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THE OCTOBER SCIENTIFIC MONTHLY

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Yuman Tribes of the Gila River. LESLIE SPIER. xviii + 433 pp. $4.00. University of Chicago.

An account of tribal distribution, economic life, social and religious conditions of the Yuman-speaking tribes of southern Arizona under aboriginal conditions. Apart from social structure, the longest section of the book is devoted to the dream basis of their religion.

Gardens and Gardening. The Studio Gardening Annual, 1933. Edited by F. A. MERCER. 128 pp. Illustrated. $3.50 cloth; $2.50 paper. Studio Publications, Inc.

The second issue of this Gardening Annual opens with a selection of illustrated descriptions of gardens from the different countries of the world. Attention is given to landscaping, rock gardens, a "carpet garden" and flowering shrubs, as well as to some lesser-known plants.

THE SCIENTIFIC MONTHLY

OCTOBER, 1933

THE UNITED STATES BUREAU OF BIOLOGICAL SURVEY

By PAUL G. REDINGTON

CHIEF, THE UNITED STATES BUREAU OF BIOLOGICAL SURVEY

History and literature are replete with instances of the interest that wild life has always had for man, and many are the examples of the inspiration that the various species have given him for creative effort in art and science and in industry and social betterment. By their very nature and relationships, the fur and game species so essential to the pioneers for clothing and food have become part of our economic and social fabric, and as a natural consequence the economic and recreational importance of wild life has led to research in this domain as a function of government. In the United States so many ramifications of the subject transcend state boundaries and so many have direct relationships to human happiness and economy that the problem has become one of federal concern. Fortunately for our wild-life resources, it has been appreciated that without scientific approach to this problem a wastefulness and an ignorant persecution of some forms as pests would result in the extermination of many more species than have already been lost to the world during recent times.

Importance of Wild-life Research

The interrelationships of the various species of wild animals to their natural environment and to man can be properly evaluated only through the application of scientific principles developed by trained biologists. In the school of experience man has learned that wild-life research is essential to the perpetuation of the harmless, interesting or valuable species, and to imposing the right degree of restraint on those that would play havoc with human endeavor if left to multiply and waste at will. Even the injurious species have exemplary traits that render them valuable to man. Thus all our native species are proper subjects for conservation in suitable environment, modifications being needed locally, as observation and study develop basic facts.

Recognizing wild life as a field for inquiry, scientists have noted and recorded facts regarding the habits of the many varieties from the time of Aristotle, who has been called the Father of Natural History. Fear that some species were in danger of extermination, including many that are interesting, valuable for food or fur or for pursuit as sport, has led within the past hundred years to cooperative efforts for their protection. Most of the societies formed for the study and protection of wild life were at first local in scope, but many were later associated into national and international organizations. One of these, founded in 1883, was the American Ornithologists' Union. Among other forms of research, this union undertook detailed studies of the migratory movements and food habits of North Ameri-

DR. CLINTON HART MERRIAM
CHIEF, 1885–1910.

can birds. Interest and recognition of the compelling necessity for continuing the work were not wanting, but funds were inadequate for conducting the investigations on a sufficiently broad scale. As a consequence, in 1885, Congress appropriated funds for the establishment of a new research unit for this purpose in the Federal Department of Agriculture. This governmental wildlife service is now the Bureau of Biological Survey. Not only ornithologists and mammalogists, but biologists in general, nature lovers, sportsmen, individually and through their organizations, and many familiar with the direct economic bearing of the work have cooperated continuously to advance the Bureau's program of research.

The directing personnel of the organization was influenced for more than 40 years by the interesting circumstances attending the selection of the first chief. Norman J. Colman, the Commissioner of Agriculture, had invited the American Ornithologists' Union to make recommendation for the office. At a special meeting of the council of the union in

MR. HENRY WETHERBEE HENSHAW
CHIEF, 1910–1916.

the office of Professor S. F. Baird, secretary of the Smithsonian Institution, Dr. C. Hart Merriam was nominated for the post by Henry Wetherbee Henshaw (1850–1930), who 25 years later himself succeeded to the office by promotion from the position of assistant. Henshaw directed the work until 1916, when, wishing to retire, he recommended as his successor Dr. Edward W. Nelson, who was thus advanced by Secretary David F. Houston and served until the Bureau had passed its forty-second milestone, in 1927, when he also retired, to be succeeded by the present chief.

The Department of Agriculture, said Secretary Henry A. Wallace, in a recent address to the nation by radio, "was created primarily for scientific research, its main job always has been a research job, and I hope research will always remain a principal duty." Throughout the 48 years' work of the Biological Survey strong emphasis has always been placed on the importance of scientific research by trained biologists. So long as we have any remnants of wild life within our boundaries, efficient management will be called for, as in the case of any other valuable natural resource, and to be efficient, management must have the fundamental basis of scientific research. Without research there could be no continued use and enjoyment of our native fauna, administration of protective laws, improvement in propagation of game and fur species, intelligent acquisition and maintenance of refuges for game and other birds and mammals, or dissemination of reliable information on any of these subjects.

Research conducted by the Biological Survey is concerned with the geographic distribution, migrations and classification and relationships of the various species in our fauna; with observations and studies of their food, breeding and other habits; with the nature of their diseases and the effects of these on man and his domestic animals; with the food plants and other environment essential to refuge establishment and proper utilization; and with methods of control of species that become a menace to farming, stock raising, game propagation and forestry.

DR. EDWARD WILLIAM NELSON
CHIEF, 1916–1927.

Some of these lines of research have been continued from the beginnings of the Survey, and others have been added from time to time to meet changing conditions. Studies in methods of controlling injurious species, for example, have been instituted within the past three decades; investigations having to do with fur farming and game propagation, with disease recognition and, where possible, with remedial measures, have been extended and intensified; as also has research in the protection of the game, insectivorous and other migratory birds that not only are valuable economically but serve to delight nature lovers and attract sportsmen to their haunts in proper season. All these more recent lines of study have had the benefit of fundamental research earlier undertaken.

Beginnings and History of the Survey

Established on July 1, 1885, as a Branch of Economic Ornithology in the Division of Entomology, the organization a year later was made an independent Division of Economic Ornithology and Mammalogy; in 1896, the name was changed to Division of Biological Survey, in recognition of a form of scientific research essential to its other activities—making surveys of the major biological regions of the continent; and nine years later, in 1905, it was given its present designation of a bureau, under the administration of Secretary James Wilson.

MR. PAUL GOODWIN REDINGTON
Chief, 1927–

MR. WALTER CLEAVELAND HENDERSON
Assistant chief, 1916–1927
Associate chief, 1927–

During its early history, and until the turn of the century, the work of the Survey was of a research nature almost exclusively. This period witnessed a succession of field surveys that rival in interest the work of the early explorations of our own West or the conquering of the wilds of other continents. The expeditions were conducted by field naturalists whose names are known throughout the scientific world. Their energy and resourcefulness enabled them to overcome difficulties that in no wise suffer in comparison with exploits that in other settings have formed the basis

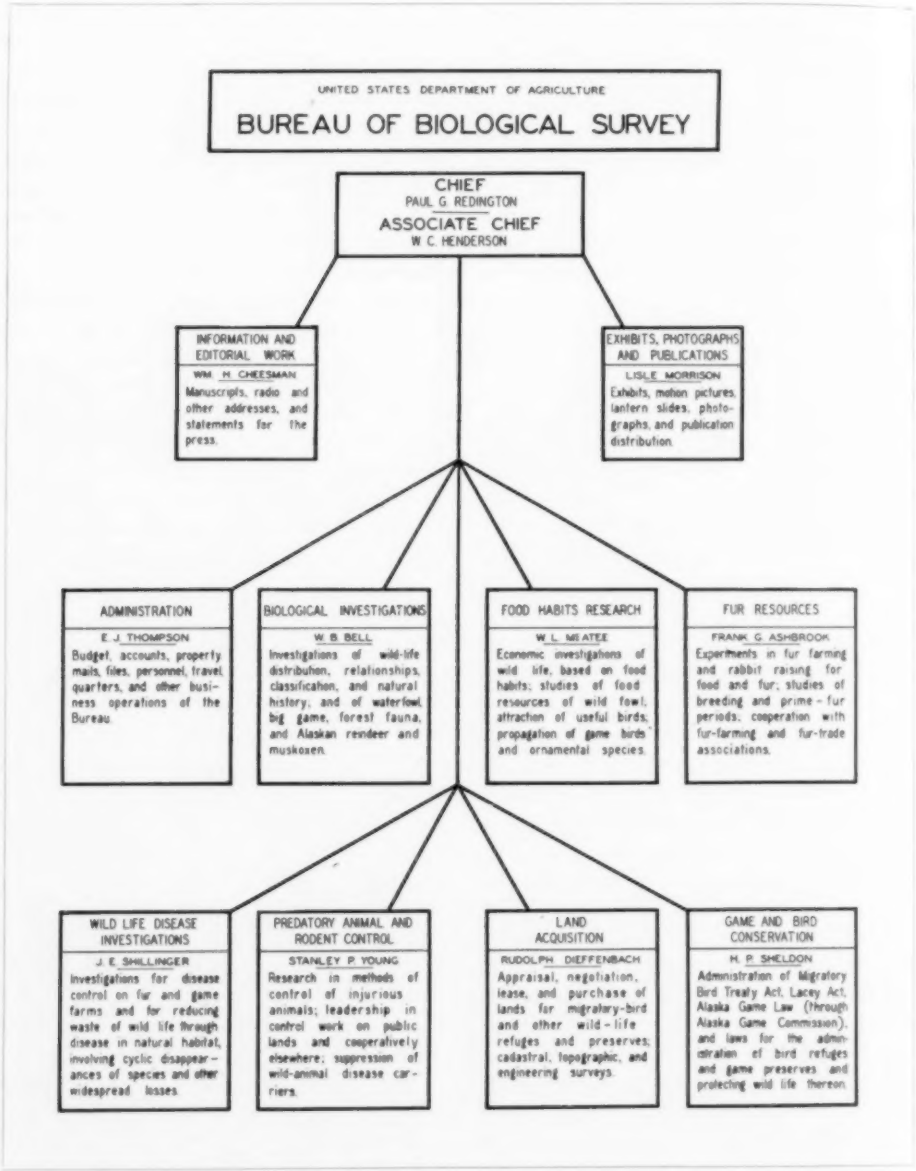
of romantic tales of absorbing interest. Through deserts whose very names were resonant of desolation and death, through unhealthful tropical jungles, to the summits of mountains carrying perpetual snow, through unexplored mazes of northern lakes, down dangerous unmapped rivers, through untrodden mountain passes, forests and subarctic wastes, by canoe, raft, pack train and snowshoe, in sun and storm these men labored. Sometimes the exigencies of travel and subsistence alone were so great as well-nigh to exhaust their utmost resources, yet there was never a day when some new fact of distribution or habits, or some specimen of scientific value, was not added to the sum total of the Survey's achievements. And through all the years of these varied quests never a man failed to return with his precious load of notes and specimens.

The elaboration and coordination of such explorations, supplemented by more detailed studies of special areas, enabled the Survey to prepare and publish maps of the natural life zones of North America and to issue some of its more important scientific reports on the classification, distribution and habits of wild life. The details of the life zones are still being filled in from year to year, as ecological and other studies develop new facts on the horizontal and vertical distribution of the native fauna and flora and on their various community associations and interrelationships.

This early period saw also the accumulation of voluminous data on the food habits of wild birds and mammals. Those of birds were learned by field observations, supplemented by gross and microscopic examination of stomach contents and identification of the various food items by comparison with extensive reference collections of seeds, insects and other objects assembled by the Bureau and classified for the purpose. Many of the results of these investigations have been made available to the public in bulletins and circulars of the Bureau and the Department and in the numbers of the *North American Fauna*, a technical series of reports of the Survey. Magazine and newspaper articles also, and radio broadcasts, as well as books published in cooperation with local agencies and with state and national organizations, have been used to bring this information to the public.

The beginning of the present century saw increased responsibilities placed on the Bureau. Certain functions of game preservation were added with the passage of the Federal Lacey Act in 1900, and three years later the first of a steadily growing system of bird refuges was established by executive order of Theodore Roosevelt. Wild-life conservation work has been extended from time to time through passage of the Alaska game laws of 1902, 1908 and 1925, the last also covering in its provisions the protection of land fur animals in the territory; and passage of the Federal Migratory Bird Law of 1913 and its successor, the Migratory Bird Treaty Act of 1918, which was supplemented in 1929 by the Migratory Bird Conservation Act, authorizing the present system of migratory-bird refuges. The last two measures were designed to carry out the provisions of a treaty for the protection of birds that migrate between the United States and Canada, negotiated with Great Britain and proclaimed by President Wilson in 1916.

The past two decades have witnessed not only increased attention to research and enlargement of functions dealing with federal protection of migrant birds, but also entry of the Bureau into the field of cooperative control of animal enemies of agriculture, stock raising, forestry and game protection. The McSweeney-McNary Forestry Research Act, passed in 1928, enables the Survey to devote more attention to studies of the relationships between forests and wild life, many species of which are found to


UNITED STATES DEPARTMENT OF AGRICULTURE
BUREAU OF BIOLOGICAL SURVEY
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W. C. HENDERSON
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FOOD HABITS RESEARCH
W. L. MCATEE
Economic investigations of wild life, based on food habits; studies of food resources of wild fowl; attraction of useful birds; propagation of game birds and ornamental species.
FUR RESOURCES
FRANK G. ASHBROOK
Experiments in fur farming and rabbit raising for food and fur; studies of breeding and prime-fur periods; cooperation with fur-farming and fur-trade associations.
WILD LIFE DISEASE INVESTIGATIONS
J. E. SHILLINGER
Investigations for disease control on fur and game farms and for reducing waste of wild life through disease in natural habitat, involving cyclic disappearances of species and other widespread losses.
PREDATORY ANIMAL AND RODENT CONTROL
STANLEY P. YOUNG
Research in methods of control of injurious animals; leadership in control work on public lands and cooperatively elsewhere; suppression of wild-animal disease carriers.
LAND ACQUISITION
RUDOLPH DIEFFENBACH
Appraisal, negotiation, lease, and purchase of lands for migratory-bird and other wild-life refuges and preserves; cadastral, topographic, and engineering surveys.
GAME AND BIRD CONSERVATION
H. P. SHELDON
Administration of Migratory Bird Treaty Act, Lacey Act, Alaska Game Law (through Alaska Game Commission), and laws for the administration of bird refuges and game preserves and protecting wild life thereon.

CHART OF ORGANIZATION OF THE BUREAU OF BIOLOGICAL SURVEY

have a beneficial influence on the forest, some to be important products of forested areas, and others to require some measure of local control.

In the nearly half century of the Survey's life, research has not been relinquished as the new service and regulatory duties have been added. Instead, the research begun with the inception of the Bureau has been continued on the same lines, improved by application of modern methods of approach. Furthermore, scientific study has been extended along new lines and has gone hand in hand with the assumption of new functions and duties, such as protection of

migratory birds, experiments in fur-farming, control of predators and rodents, management of upland game and selection of areas suitable for reservation as migratory-bird refuges.

Organization of the Bureau's Research Work

As now organized, the work of the Bureau of Biological Survey in divisions and offices other than central administrative is conducted through seven divisions, five of which are engaged in research, and in four of these research is a major function. The five are as follows:

(1) The Division of Biological Investigations continues the original work of the Bureau in faunal geography and in the classification and life histories of species. To these lines of study have been added forest-fauna research in cooperation with the Forest Service; investigations for the improvement of Alaskan reindeer herds, including cross-breeding with native wild caribou; experiments in restocking Alaskan areas with transplanted musk-oxen; and new studies of water-fowl, essential to the administration of the Migratory Bird Treaty Act.

(2) The Division of Food Habits Research, continuing the original work in identification of stomach contents of birds and field study of economic ornithology, has also, through establishment of a field laboratory, intensified its research on the food habits of predatory and other mammals, as a basis for scientific pest-control operations. Other added investigations involve the encouragement of useful and control of injurious species, the investigation of food resources of migratory-bird refuge areas, the propagation of aquatic and upland game birds in captivity, and, in cooperation with associated sportsmen, the management of upland game and the increase of quail and other species on preserves.

(3) The Division of Fur Resources has continued original studies of economic uses of fur animals, and now, through establishment of two field stations, conducts fur-farming experiments in the propagation of foxes, martens, minks and other valuable species, and makes investigations in rabbit raising for both food and fur.

(4) A Disease Investigations Project, under which studies are made of the maladies of water-fowl and other game birds, foxes and other wild stock on fur farms and elk and other big game, was established in 1931, to consolidate work in disease control formerly undertaken in the three foregoing research divisions.

(5) The Division of Predatory Animal and Rodent Control includes a project designated Control Methods Research, under which pharmacological and other studies are made of methods of control of injurious animals with the least menace to harmless species; and baits for use in the control of rodents of diverse feeding habits are developed and processed.

In addition to its research activities, service in predatory-animal and rodent control is rendered by the last-named division in cooperation with state and other agencies. Regulatory and related functions are performed by the remaining two of the seven divisions, as follows, all of which benefit by the basic research of the Bureau:

(6) The Division of Land Acquisition, operating under the Migratory Bird Conservation Act, is concerned with the acquisition of land and water areas as refuges for migratory birds and other forms of wild life. When areas are found by the Survey to be biologically suitable, as regards site, physical environment and food resources, this division determines ownership and market value, examines and appraises them, and negotiates to reach equitable price agreements preliminary to consideration and approval by the Federal Migratory Bird Conservation Commission of acqui-

ELK FEEDING AT WINTER REFUGE OF THE SURVEY IN JACKSON HOLE, WYOMING

sitions recommended by the Bureau. Other work involves compilation of land records and cooperation in expediting payment for lands when title is obtained, and surveying areas acquired and establishing and marking their boundaries to prevent unauthorized use and trespass, with a view to adequate protection of the wild life.

(7) The Division of Game and Bird Conservation administers the Lacey Act, regulating interstate commerce in birds and mammals and importations of foreign wild species; the Migratory Bird Treaty Act, through a force of federal game protectors; laws protecting bird refuges and wild life and property thereon; and, through representation on and cooperation with the Alaska Game Commission, the Alaska Game Law. This division also administers the approximately 100 wild-life refuges now under jurisdiction of the Bureau, all of which are potential natural laboratories for wild-life research.

The work of the Biological Survey, to-

PART OF THE SURVEY'S BUFFALO HERD AT WIND CAVE GAME PRESERVE, SOUTH DAKOTA

gether with its numerous publications over nearly half a century, has been a potent factor in increasing the numbers of students of wild life. The Survey has been instrumental also in bringing wild-life conservationists and the general public more and more each year to a realization that protection of our game, fur, insectivorous and other species is of vast economic and recreational importance and involves enactment and enforcement of laws that have their foundation in scientific fact.

Extension of the protective principle to the fur-bearers, song and insectivorous species and other denizens of the wild, including also the game species for reasons other than sport, is being more and more demanded as our people become better informed regarding the economic and social values of wild-life management and the need of preserving areas of natural habitat. Better now than ever before the public understands the necessity of perpetuating the benefits that accrue to man through preserving about him in suitable wilderness areas representatives of the great variety of species still remaining in our native fauna.

Some Results of the Survey's Wild-Life Research

Numerous local scientific investigations by the Biological Survey and specific portions of its larger undertakings have been completed at various periods of the past half century, but wild-life research as a whole is a continuing major project. Dealing as it does with living organisms, some of them highly migratory, and these and others in constantly changing environment, this work is ever confronted with new problems and with old problems apparently solved but arising in new guise. Thus, it can not be said that any phase of wild-life research has been fully brought to completion, but at the same time distinct progress and gratifying accomplishment have been and constantly are being registered.

Studying stomach contents of birds
Mr. W. L. McAtee at microscope.

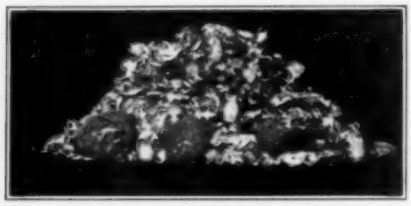
Research on Food Habits of Wild Life

The Biological Survey has made notable contributions to the literature of economic ornithology and to a lesser extent to that of economic mammalogy and herpetology. It has issued many publications on the food habits of mammals, some on reptiles and amphibians, and more than 250 on the food of birds. These publications on birds present in detail the economic status of about 500 species. Those of a popular nature on the economic status of birds and measures for attracting and protecting them are estimated to have been distributed in the past 48 years to the extent of more than 7,000,000 copies. With the more technical reports, these have had an untold influence for federal, state

Reptile studies by Dr. Remington Kellogg, formerly of the Survey.

and local bird-protective legislation and regulation and also for bird conservation internationally. Several of the reports involved the relation of birds to various insect outbreaks, and in addition to official and cooperative formal publications, a great volume of information on the status of wild species has long been disseminated through periodicals, the press, by radio, in manifolded leaflets and in the Bureau's day-by-day correspondence.

Other results of research on the food habits of birds have had wide application in solving problems in the introduction and protection of game, insectivorous and other useful birds and in the propagation of upland and aquatic game birds as well as in improving the nat-

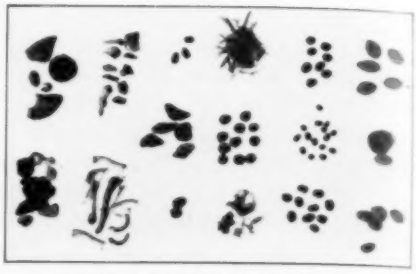


SKULLS OF FIELD MICE

FROM OWL PELLETS TAKEN AT A ROOST IN SMITHSONIAN INSTITUTION TOWER, WASHINGTON.

ural food resources of birds. These studies have thus made possible a continuing utilization of the birds themselves and of their services and an enduring enjoyment of their beauty of motion, song and color. In addition, these studies have enabled the Survey to recommend measures ranging from local control of injurious birds to the care of aviary and ornamental species in captivity.

Maintenance and increase of birds that have been demonstrated to be beneficial means increased destruction of insect pests and thus reduced crop losses. Local control of injurious birds has the same ultimate benefit. County agents have estimated that destruction of English sparrows in Utah by methods recommended by the Survey resulted in

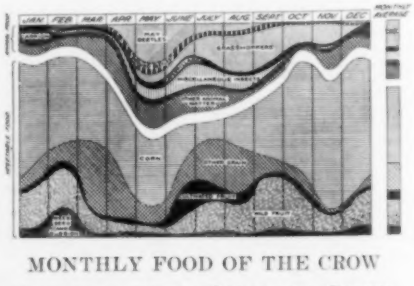


TYPICAL FOOD OF CROW

AS SEPARATED IN STOMACH CONTENT EXAMINATION.

savings of $337,000 in three years. Similar control has been accomplished at the North Dakota Experiment Station and at certain Army posts, and control of birds destroying rice, other grains and fruit in California in some cases has reduced the damage to a tenth of what it was before.

Research on the propagation of the plants found most important as wild-duck foods has assisted in building up a growing industry in the sale of these plants. Investigations for the improvement of wild-fowl feeding grounds has been a factor in increasing the value of many properties—in one case the gain was tenfold. Studies in improving the environment of upland game birds have set new standards for game-bird management, and the published report on one, the bobwhite quail, embodied the most comprehensive account of any American game bird that has ever been published. Acting on the findings and recommendations has doubled the production of quail on extensive southern



MONTHLY FOOD OF THE CROW

AS CHARTED BY THE BIOLOGICAL SURVEY.

holdings, and the financial gains alone would be a large figure, considering the high value set on quail hunting.

During the past three years examinations have been made of the waterfowl food resources on more than four million acres, and about a sixth of the total number of projects involved were recommended for acquisition by the government for migratory game-bird refuges. Though the saving of game birds realized by the establishment of these refuges is of economic as well as social and esthetic importance, it would be impossible to state the value in dollars.

Research on Methods of Pest Control

Through research in methods of suppressing injurious rodents and predatory wild animals the Biological Survey has increased efficiency in the use of baits and traps, determined the minimum dosage for various species, improved mechanical preparation and packaging, and reduced the cost of control. Knowledge gained through this research has also made it possible to select, prepare and expose poisoned baits and to set traps so as not seriously to endanger animals other than those for which they were intended.

This phase of the Bureau's investigations has demonstrated that quail, pheasants, grouse and domestic poultry are surprisingly immune to strychnine poisoning and that grain baits can be so prepared and distributed as not to endanger birds of the gallinaceous group, the ones most likely to take these grain baits. The development of red squill as a poison specific for rats has made it possible to safeguard the home and the premises where rat control has to be undertaken. Safeguards also have been designed to minimize the danger to fur animals in areas where the ravages of predators must be curbed either by use of poison or by trapping. A special attachment for traps was invented in the Biological Survey, a device that keeps the trap from being sprung by animals or birds lighter in weight than the predator for which it is set.

Special studies are being made of thallium for local use against rodents that successfully resist other control methods—notably the California ground squirrel, a carrier of the bubonic-plague organism—and of treatments in case of any accidental human poisoning. Reported experiments have demonstrated that there is no danger of secondary poisoning from cooking and eating game birds that may have taken thallium grain baits exposed for rodents. This poison is used in restricted areas only, and there its use is closely supervised by state and Survey field leaders.

Improvements in control methods have resulted from findings as to the minimum lethal dosage required in baits for coyotes and other predators, which has had the effect of greatly reducing the quantity of poison used locally. A tablet also has been developed containing the proper quantity of poison for coyote and other baits. Cooperative rat-riddance campaigns have been simplified by the Bureau's introduction and demonstra-

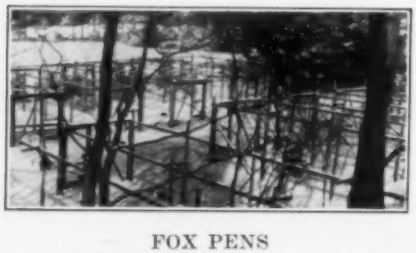
SURVEY'S RESEARCH IN METHODS OF CONTROL

Left, Mr. J. C. Ward, making laboratory tests; *right*, Mr. F. E. Garlough, checking efficiency in field experiments.

U. S. RABBIT EXPERIMENT STATION OF THE BIOLOGICAL SURVEY, FONTANA, CALIF.

tion of ready-prepared and canned baits of varied composition, with red-squill powder as the effective agent. Other improvements that owe their origin to this part of the Survey's control-methods research include mechanical processing of strychnine baits to conceal the bitter taste and thus render them more acceptable, and development and application of catnip-oil and other scents as lures to traps placed for mountain lions, bobcats and other predators. Other accomplishments in control-methods research have ranged from improvements in methods of trapping wolves in the United States and Alaska to the devising of means for repelling bats from obnoxious roosts established in human dwellings.

The importance of research in pest control is appreciated from the benefits accruing to farmers and stock growers, foresters and game protectors, warehousemen and the individual householder. Rodent pests each year cause enormous losses in farm crops, forest and fruit trees and in range forage and stored products; and predators commit serious depredations on cattle, sheep, pigs, goats, poultry and wild game animals and birds. Compared with these losses, the cost of the research is insignificant.



FOX PENS
AT THE SURVEY'S FUR ANIMAL EXPERIMENT STATION, SARATOGA SPRINGS, NEW YORK.

EXPERIMENTS IN FUR-ANIMAL PRODUCTION

The Survey's research in fur resources, while of special interest to trappers, fur farmers, legislative committees and wildlife conservationists, is of benefit also to the fur trade and to the consumer of fur. Many of the problems confronting these various groups have found at least partial solution in the technical information coming from the Bureau's research. About 80 foreign countries contribute to the fur annually consumed in this country, which aggregates more than that of any other country in the world. With our consumption greater than our production, and with the native stocks constantly decreasing before human occupation of their haunts, it becomes necessary for scientific research to bridge the gap between domestic supply and demand. Accordingly, experiments in fur farming were undertaken by the Survey.

At the two fur-animal experiment stations maintained by the Biological Survey, one in New York, established in 1916, the other in California, in 1927, many species are studied—foxes, martens, minks, badgers and other native fur-bearers and fur rabbits. The results are made available by bulletins and other means of public information, chiefly for the benefit of fur farmers and of persons who contemplate engaging in the industry. Throughout, the Survey's work in fur production has had the close cooperation of educational institutions, state conservation departments, private organizations and associations of the fur trade. In 1930 the Bureau placed an exhibit, supplemented by a special pub-

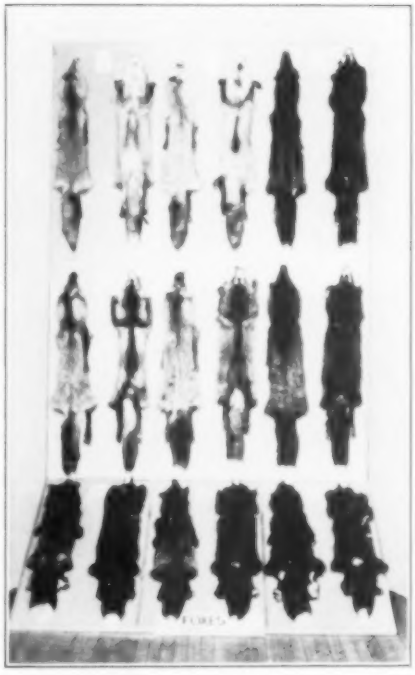
lication in English and German editions, at the International Fur Trade Exposition and Congress, at Leipzig, Germany, with results mutually beneficial to this and to other countries participating.

Studies at the Bureau's experiment stations and at many fur farms throughout the country have developed important information regarding the several species raised for fur and have resulted in reduced costs of production, improvements in pens, dens and sanitary housing and elimination of wasteful and inhumane methods. Anatomical data regarding the many varieties of fur animals have been placed on record, and the mating and gestation periods of the marten have been established, thus for the first time making it practicable to breed this valuable fur species in captivity. Investigations of pelt value have included studies of the effect of sun and shade on fur quality, and a genetic basis has been established for control of color phases of foxes along Mendelian lines.

Research in rabbit production has included studies of quality and texture of the fur of various breeds, the beneficial effects of crossbreeding on both meat and fur-producing rabbits, and the influence on growth to market age by feeding various rations, including hays, grains, mashes and cod-liver oil and other supplemental feeds. The importance of these investigations is evident from the large investments in the business, particularly in the Pacific Coast states. Rabbit meat has become a staple in many markets, and rabbit pelts are being used in the fur trade in greater quantity than those of any other fur animal.

Wild-Life Disease Investigations

Critical studies of wild species propagated under controlled conditions and observations of wild-caught individuals have served to emphasize that both are subject to a wide variety of diseases. Research to provide a basis for controlling or preventing outbreaks is important, therefore, to the fur and game farmer and to those concerned with the conservation of the species in the wild. The Bureau's wild-life disease investigations have been the means of reducing losses and enabling many propagators to continue their occupation on a profitable basis.



COLOR PHASES OF FOXES

AS DEVELOPED BY THE SURVEY ON MENDELIAN LINES.

As a result of studies of bacterial, parasitic and other wild-life diseases by the Survey and its cooperators at the University of Minnesota and elsewhere, a number of epizootics have been stamped out on fur and game farms. Such elimination has saved many propagation projects from bankruptcy, for when abnormal conditions occur in wild animals or birds they are frequently of such severity as to wipe out large portions of the exposed populations in the wild as well as a high percentage of the stock on game and fur farms.

RESTRAINING FOX FOR DISEASE TREATMENT.

Administrators of wild life on private estates and preserves and on extensive areas in the wild are more and more being acquainted with the seriousness of disease outbreaks in the stock for which they are responsible. Information as developed by the Survey is made available for their use to aid in eliminating as many of the hazards as possible. It is necessary, however, that such research proceed and that investigations be made sufficiently extensive for satisfactory control under all circumstances.

Facts already developed show that there are cycles both of abundance and of scarcity in many species in the wild—rabbits, for example—and that local depletions frequently result from disease, the spread of which is facilitated where the victims are densely crowded. Some of these wild-life diseases are communicable to man, including tularemia, rabies, bubonic plague and spotted fever. A thorough knowledge of these diseases of wild life facilitates the application of protective and remedial measures.

One of the most important results of the Bureau's research in wild-life diseases was the discovery of the cause of the celebrated western wild-duck sickness, which in many areas has caused the death of more wild fowl in a season than fell before the guns of the local hunters. At first considered to be caused by excess alkalinity of certain waters, it was finally developed by the Survey to be of bacterial origin, a form of botulism caused by *Clostridium botulinum*, type C. The remedy indicated is proper control of water level and movement and in some cases treatment of rescued birds by change of food and environment for a period prior to release.

Other discoveries have had to do with a condition on fox farms formerly termed generally "distemper" but now known to be several distinct diseases, among the most disastrous being infectious fox encephalitis and fox paratyphoid. It is not yet known how prevalent these diseases are in the wild, but under controlled conditions their incidence appears to correspond to the density of the fox population. Comprehensive studies also have been made of bob-white quail, their diseases and methods of control.

PINTAIL CURED OF BOTULISM RELEASED AT FIELD LABORATORY BY MR. E. R. KALMBACH.

In addition to their infectious diseases, many species are subject to rickets and other nutritional maladies, to lead and phosphorus poisoning contracted when picking up shot and particles of the chemical with grit on their feeding grounds and to losses from water pollution. So many are the dangers menacing wild life in contact with the human population that it is little short of amazing that so many of the species still survive. Until the fact-finding investigations undertaken by the Bureau have been sufficiently extensive, adequate control measures can not be recommended in all cases. In the interim, thoughtful administration of our wild-life resources calls for proper management of habitats in the wild and strict measures of sanitation on fur and game farms. With better fundamental knowledge of requisite sanitation and of causative organisms will come a more adequate system of disease prevention and treatment.

Studies of Faunal Distribution and Relationships

Scientific investigations of wild-animal life, continued by the Survey for nearly half a century, have resulted in the accumulation of extensive and systematized files and in the publication of more than 800 formal reports, official, and in scientific periodicals, including many monographs on the North American fauna and faunal studies of states and other large areas. Such basic information on the classification, distribution and habits of species enables the Survey to plan effectively its other work in wild-life conservation and control and to cooperate with game-conservation boards, agricultural and live-stock associations, educational institutions, experiment stations and other organizations. In addition to its provisional life-zone map of North America, the Survey has published detailed maps of the life zones of many of the states, thus bringing to higher perfection the map of the continent as biological surveys are completed over large areas.

Big-game conditions have been studied with a view to recommendations for improving environmental factors on federal preserves and national forests and parks, the chief species involved being deer (on the Kaibab Plateau, Arizona, and in Pennsylvania), elk (Yellowstone Park region and adjacent forests), wild life generally in many national parks, and antelope, mountain sheep, caribou and moose. The relationships of these animals and of predators and rodents to their habitat and to the industries of agriculture and stock-raising are constantly being observed and studied.

CHECKING GEOGRAPHIC DISTRIBUTION RECORDS OF MAMMALS

Mr. E. A. Preble studying map.

One result of the regional biological surveys has been the assembling of collections of mammals and birds and of information about them that are of incalculable scientific value and afford a practical basis for determining the occurrence, distribution, habits and needs of species that are of importance economically and otherwise. These data have been used in formulating treaties and other agreements looking to the protection of migratory birds, in furthering educational programs involving sound agricultural development and land utilization and in determining administrative policies in wild-life management.

Early in the history of the Biological Survey, Dr. C. Hart Merriam, the chief, developed and applied the laws of geographic distribution, based on temperature, altitude and slope exposure, a result of which has been the Survey's mapping of the natural life zones of the continent, the details of which are still being filled in from time to time. Developments of the life-zone research have been evidenced in studies of animal and plant ecology, and in connection with the study of factors limiting the range of crops and the areas suitable for fur farming. Research in geographic distribution has also resulted in the announcement of laws on the speed of bird migration northward in spring, as correlated with successive isotherms. Studies of bird movements and other phases of their life histories are being supplemented through use of data on bird banding, the central records of which, and the direction of activities in North America are in offices of the Biological Survey.

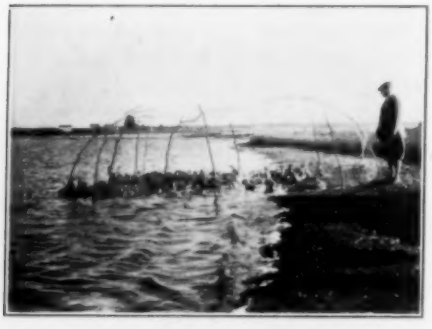
From the Survey's mammal research have been evolved new methods of field collecting, museum labeling, arrangement and care of specimens, training field assistants and publishing specific descriptions and generic monographs. Prior to the entry of the Biological Survey into the field only the most obvious types had been described, and hundreds

SKULLS IN THE BIOLOGICAL SURVEY MAMMAL COLLECTION

BEING CLASSIFIED BY DR. H. H. T. JACKSON.

of specimens formerly unknown are now named and recorded, with type specimens available in study collections. So great has been the impetus to mammal study and so numerous have been the additions to the recognized varieties of mammals, due to more general recognition of the value of distinguishing characters, based on color and peculiarities of skull and teeth, that the mammals are now almost as well known as the birds. In fact, a confrere once remarked that Merriam had named more animals than did Adam!

The standards set by the early work of the Survey have resulted in the accumulation of a wealth of material in the museums of the country, of much better quality than had ever before been available. The importance of maintaining and building up the Survey's collection of scientific specimens is evidenced by the fact that these enable the Bureau to identify specimens and even fragments that are of economic importance, including determination of identity of species that carry disease, destroy or protect crops, or are otherwise detrimental or useful to man, sometimes for identification to prevent fraud in bounty payments. The collection is also used in scientific investigations by the Bureau's staff and by cooperating institutions.



WATERFOWL STUDIES

226 PINTAIL, REDHEAD AND MALLARD DUCKS TRAPPED BY BIRD-BANDING COOPERATOR OF THE SURVEY.

SCIENTIFIC BASIS FOR BIRD PROTECTION

In the field of investigations of migratory birds, the work of the Survey provides a rational basis for conserving a natural resource that has important relations to agriculture and forestry and one that supports large investments in recreational facilities, including hunting, camping, transportation and the production of outing equipment, and provides large financial returns to land and marsh owners, guides and others rendering services to vacationists, sportsmen and other outdoors men.

Through extended surveys of migratory birds in the United States and adjacent countries, the Bureau has assembled a vast amount of information, on which it has based reports, charts and maps for use in drafting regulations under the Migratory Bird Treaty Act and in educational work. Bulletins have been issued to make available information on the economic value of birds, abundance of waterfowl, conditions on their breeding and wintering ranges, their migration routes and the effect on their future of drainage, water pollution, drought, food supply and hunting practises. On such basis, the United States, nationally and by state action, has built up the best system of bird-protective laws on the statute books of any nation, and the Federal Government is providing on marginal and other lands a system of inviolate sanctuaries for wild fowl.

Establishment of bird-protective laws on a research basis has produced wider appreciation of the importance of respecting seasons when the birds have paired off for breeding. Two outstanding accomplishments under the federal laws protecting migratory birds have been the abolition of spring shooting and of the sale of ducks, geese and other waterfowl.

Studies of the wild life of forests, intensified in recent years, are providing exact knowledge of forest species, their life histories, abundance and ecological relationships, including their effect on forest pests, on planted seeds and seedlings and on forage production on forest-grazing areas, soil fertility and erosion. Potential improvements of forests by

PART OF HERD OF MUSK-OXEN

TRANSPORTED TO ALASKA FROM GREENLAND FOR RESTOCKING PURPOSES.

HERD OF ALASKAN REINDEER

BEING STUDIED BY SPECIALISTS OF THE BIOLOGICAL SURVEY.

wild life include the planting of colonies of beavers to demonstrate methods of improving water storage, increasing fish and fur production and checking run-off and erosion.

Investigations in Reindeer and Musk-ox Production

Among research accomplishments by the Survey in Alaska have been the successful reintroduction of musk-oxen in the territory by transportation from Greenland and improvement of conditions affecting the reindeer herds. Musk-oxen, once important in the Alaskan fauna, were exterminated in the territory shortly before European occupation. The present effort is to rear the introduced young animals at an experiment station until they reach breeding age, so that they may reestablish the species in the northern parts of Alaska. Under practical management on the extensive grazing areas of the region they may become an important game or domestic resource.

Alaskan reindeer, introduced from Siberia by the Bureau of Education more than 40 years ago, have rapidly increased and now present new and pressing problems that affect the animals themselves, the grazing resources and the economic and social welfare of the native and white population. Biological Survey investigations in coastal, insular and interior Alaska are aiding owners to cope with the parasitic and other diseases of reindeer, to adopt improved methods of herding and range management, and through proper care and selective breeding, to improve the quality of the animals for meat production. Experiments in crossbreeding with native caribou have been conducted successfully with a herd maintained on Nunivak Island, the crossbred animals averaging materially heavier and having better conformation for meat than either of the parent forms. In the reindeer herds the native and white population have an important industry that means much both industrially and socially. In the improved practises developed and recommended by the Biological Survey they have a basis for an enduring industrial civilization.

WEST INDIAN HURRICANES[1]

By Dr. MELVILLE T. COOK

PLANT PATHOLOGIST, INSULAR EXPERIMENT STATION OF PUERTO RICO

HURRICANES in the West Indies have been known since the coming of the white man. In fact, the name "hurricane" is derived from an Indian word which the Spaniards adopted and which was taken by the English with slight modification of pronunciation. The early records show that these storms were dreaded by the Indians and settlers. Columbus met with one of these storms on his first voyage, which forced him to take refuge in a harbor of Santo Domingo. On his second voyage, while at anchor at Cape Santa Cruz (July 16, 1494), "a violent hurricane occasioned the admiral to declare that nothing but the service of God and the extension of the monarchy should induce him to expose himself to such dangers." July 1st, 1502, he suspected the approach of a hurricane and asked permission to enter a harbor of Santo Domingo, which was refused. He then put to sea and within the next twenty-four hours, twenty ships and all on board were lost. Columbus describes this storm as follows: "The gale was terrible, and in that night my vessels parted company, every one expecting death, and each considering it certain that the others were lost. With the exception of Job there never was a man who would not have died in despair: When to save my life and that of my son, brother, and friends, I was at such a time forbidden the harbors, which by God's permission, I had gained for Spain, sweating blood. The vessel in which I was, weathered the gale marvelously; it pleased God that she received no damage whatever. My brother was in the unsafe vessel, and, next to God, was the means of saving her. In this gale we made Jamaica." Many hurricanes have been recorded since that time, and the average has been about five per year for the entire Caribbean area. Most of these storms do little or no damage, because they never strike land, but some of them have been very destructive of both property and life and the cause of much suffering among the survivors. In fact, the suffering was so great that it was sometimes necessary to use military force to prevent the early Spanish settlers from returning to Spain.

The last destructive hurricane in Puerto Rico, previous to the Spanish-American War, was the San Narcisco,[2] of October 29, 1867. The first hurricane after the Spanish-American War was the San Ciriaco, August 8, 1899. The loss of life and property at that time was enormous. It was estimated that 3,000 people were killed or drowned. The United States Weather Bureau was not so well established in the West Indies then as at present, and the communications by telegraph and telephone were very poor. The storm came on the unsuspecting people in the night and was accompanied by a heavy downpour of rain. The rivers rose rapidly and many people were carried out to sea. Following that date there were a few small but no severe hurricanes in Puerto Rico[3] until September 13, 1928, when we were struck by the San Felipe, which came in the daytime and swept across the island diagonally from the southeast to the northwest (Map 6).

[1] The meteorological data have been verified by a member of the U. S. Weather Bureau. Photographs by courtesy of the U. S. Forestry Service.

[2] It is the custom of the Spanish-American people to designate these storms by the name of the Saint on whose day they occur.

[3] In August, 1926, a hurricane caused rather heavy losses over a small area of the southwestern part of the island.

The path of this storm was 150 or 200 miles wide and the danger zone 50 or 75 miles wide. The maximum velocity at San Juan was between 9 A. M. and 3 P. M.

The next hurricane was the San Nicolás, which struck the island between 9 P. M. and midnight, September 10, 1931. This was of very small diameter and very mild, as compared with the other two. It followed the full length of the island, the vortex being a little north of the north coast and the velocity about 90 miles per hour.

The third was the San Ciprián, which swept the north part of the island between 8 P. M., September 26, and 6 A. M., September 27, 1932. The path of this storm was about 50 miles wide and the velocity about 120 miles per hour. The destruction was very great, but was less than the San Felipe, because the path was not so wide.

These storms originate in the Atlantic Ocean usually during the months of August and September, although there are many records for July and October and some few for other months. They usually sweep across the Caribbean Sea or turn northward and come to an end on the continent or in the North Atlantic Ocean. If they strike land, we hear about them, but if they blow themselves out at sea without destruction of shipping they become records for the Weather Bureau only. These storms have two movements, a rotary movement (counter clockwise[4]) in which the velocity may be as great as 150 miles or more per hour, and a forward movement, which may be as slow as eight miles per hour or even less under certain conditions. There is always a small calm area (the vortex) in the

[4] Hurricanes south of the equator blow in the opposite direction.

BUILDINGS AT THE FORESTRY STATION AFTER THE SAN CIPRIÁN

NOTE THE STEEL FLAG POLE IN THE FOREGROUND.

center. The velocity is greatest next to this calm area and gradually decreases towards the circumference. The region in the path of the vortex is struck by the outer part of the storm, which becomes more and more severe until the calm area arrives when there is a sudden cessation for a few minutes to a half hour or more depending on the size of the storm. With the passing of the calm area the region is struck by the second half of the storm which is blowing in the opposite direction. The points affected by the storm not crossed by the vortex experience a gradual rise and fall in the velocity of the wind.

Four other hurricanes of recent years that should be mentioned are the one that struck Havana October 20, 1926; the one that struck Santo Domingo September 3, 1930; and the one which struck Belize August 15, 1931. All these hurricanes were the causes of heavy losses of property and lives and are fresh in the memory of the readers. The fourth is the one that struck Cuba November 9, 1932, and was accompanied by a storm wave which killed or drowned about 2,500 persons. Two hurricanes struck Florida in 1926, and the one that struck Havana was felt in the southern part (see maps 1 and 5).

The paths of the storms of the past four years are very interesting. There were four storms in 1928 (Map 2). The first passed to the east of the West Indies, traveled northwest and did little or no damage. The second was almost parallel and to the west of the first and did very little damage. The third passed over some of the Lesser Antilles, moved almost due west and was of very little importance. The fourth, which was the San Felipe, took the same gen-

RESULTS OF THE SAN CIPRIÁN.

NOTE THE FOLIAGE STRIPPED FROM THE TREES. TWO ROYAL PALMS ARE IN THE FOREGROUND.

COCONUT PALMS AFTER THE SAN CIPRIÁN.

IN MANY PLACES THE PALMS WERE SNAPPED OFF CLOSE TO THE GROUND.

eral direction as the first and second but between them the greater part of the time.

There were three hurricanes in 1930 (Map 3). Two were of little importance, but one struck Santo Domingo and caused great losses of both lives and property.

There were five hurricanes in 1931 (Map 4). The first traveled almost due west and struck Belize with great loss of life and property. It was the most destructive of any during that year. The second swept to the north, a little west, over Puerto Rico, and was of little importance. The third originated well to the north, traveled almost due west, across Santo Domingo and the Isle of Pines, turned northeast, crossed Florida and died in the Atlantic Ocean. The fourth followed the course of the first very closely and did very little damage. The fifth was the San Nicolás, which also traveled almost due west, brushed the north coast of Puerto Rico and Santo Domingo.

There were four hurricanes in 1932 (Maps 5 and 6). Two were of little importance. The third was the San Ciprián, which struck Puerto Rico and was very destructive. The fourth struck Cuba, killed about 2,500 people and caused heavy loss of property. This hurricane came very late in the season and its forward movement was very slow, but it increased in force after turning north.

The approach of a hurricane is preceded by short periods of wind and rain, which become longer, stronger and more frequent until they merge into a continuous storm. The storm roars, howls and shrieks, but the most characteristic sound is a very shrill whistling. The intensity of the storm varies after it reaches its maximum velocity. The noise due to falling buildings, uprooting of trees and other destruction depends largely on the location, but the noise made by the storm is usually greater than that due to the destruction.

The writer was located about 20 miles northeast of the vortex of the San Felipe hurricane, about 6 or 8 miles south of the vortex of the San Nicolás and about one half mile or less north of the vortex

of the San Ciprián. Squally weather which preceded the San Felipe started about 4 P. M. the day (Wednesday) before and increased in intensity until 9 A. M. the following day. From that time until about 3 P. M. the velocity was at its maximum of about 150 miles per hour. Heavy pieces of zinc roofing were ripped from the houses and carried into the air like sheets of paper. This was followed by the woodwork. These and many other articles flying through the air were a source of great danger to persons and live-stock without shelter. The streets and roadways very soon became a tangle of broken trees, poles and wires. The writer lost a part of his roof a little before 3 P. M. The storm subsided rapidly after 3 P. M. and many people were on the streets by 5 P. M., but squally weather continued until 6 A. M. the next day. The contents of nearly all houses were damaged and in some cases entirely destroyed. The more unfortunate people utilized every possible kind of shelter from flying objects; under beds, tables, kitchen sinks, and occasionally under the floors of the houses. Sometimes very substantial buildings would be severely damaged, while small frail buildings beside them would be very slightly damaged. A steel flag pole (without flag) was bent at an angle of 45 degrees.

The San Nicolás was preceded by squally weather and came with a velocity of about 90 miles per hour at about 9 P. M. and lasted until near midnight. Many objects were blown against our house, but we had very little damage. We were less than one half mile from the vortex of the San Ciprián hurricane. This was preceded by squally weather and reached its maximum of 120 miles or more at about 11 P. M. It began to subside about 3 hours later. Many heavy objects were blown against our house, and we thought the entire roof had blown away. Much water came in and we were kept busy moving furniture and covering various articles. After the storm began to subside we could see by the flashes of lightning[5] that the roofs of many of the neighboring houses had been blown away, but with the coming

[5] There is a belief among the people that when lightning accompanies a storm, it will not be a hurricane. This was an exception. The literature shows that a few hurricanes have been accompanied by lightning.

A SMALL SUGAR CENTRAL THAT WAS DESTROYED BY THE SAN CIPRIÁN.

of daylight we found that we had lost a small part of our roof. However, both roof and ceiling were raised an inch in the front part of the house. One of the neighbors who had a lantern called and we visited a few of the neighbors and rejoiced to find that there were no fatalities among them. One of our neighbors who lost his roof was compelled to shelter his family with a bed mattress for a time and then sought refuge in the servants' quarters, which were not damaged. I found him and his wife and five little children (two with measles), there later in the morning. With the coming of daylight we found that most of the houses in the neighborhood were almost or completely unroofed. Roofing nails which were carried for 100 yards were shot through my windows like bullets.

With the coming of daylight the writer made a short tour of investigation into a section occupied by the very poor peons. Nearly every house was in ruins and the poor people were trying to salvage a few of their meager possessions. The philosophy of these people is surprising to any one who does not know them. They have very little of this world's goods to care for and so long as they do not suffer personal injuries they do not worry. We could hear them hammering as soon as it was light enough to see, and within a few hours practically all these people had temporary shelters which they constructed from the ruins.

In this connection it may be well to say that statements concerning the losses of property are likely to be misunderstood by the people of the north unless they are familiar with the character of our residences. Many of the old Spanish buildings are still standing. They have very thick walls of masonry and flat tile roofs without projecting eaves. They were not damaged to any great extent. The American bungalow type of house, with steel reinforced walls and corrugated galvanized roofing, has become very popular in recent years. The walls of these residences stood, but

AFTER THE SAN CIPRIAN.

NOTE THAT THE FOLIAGE IS STRIPPED FROM THE TREES.

NOTE THE SMALL SHELTER CONSTRUCTED FROM THE RUINS.

most of the roofs were blown partly or completely away. This was partly due to the failure to anchor the roofs properly and partly to the fact that the projecting eaves are exceptionally favorable for hurricane damage. Most of the frame houses were damaged, some of them beyond repair. The great majority of the people are very poor (as is the case in all tropical countries) and live in frail little houses constructed of fragments of lumber, old roofing, old boxes, palm leaves, etc. These houses are destroyed in great numbers. The money value is very small, but they are of such simple construction that most of them can be rebuilt within a few days.

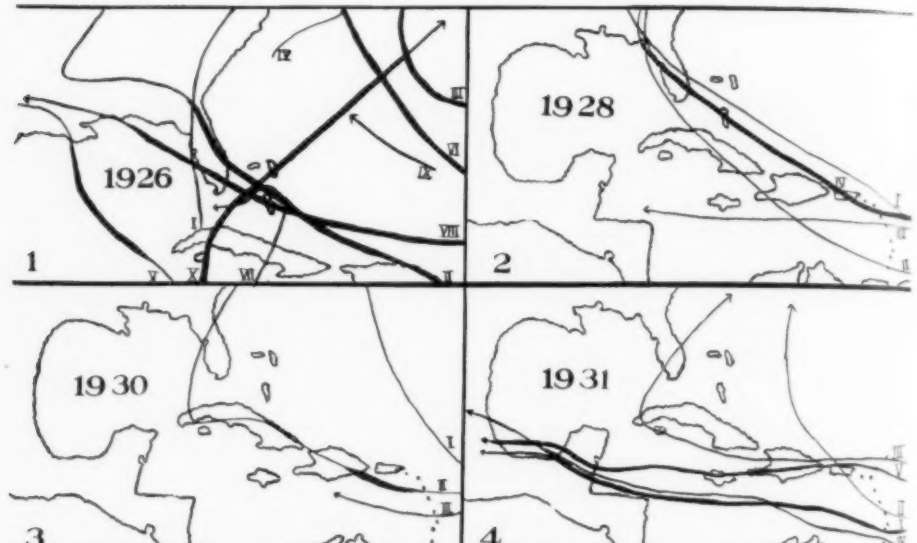
Thousands of trees were broken or uprooted. The leaves were stripped from many species of trees and shrubs and the country resembled a northern landscape in midwinter. Thousands of coconut palms were uprooted or snapped off near the level of the ground. The tops of those that remained standing were so torn and mangled that they presented a sorry sight. The luxuriant growths of tropical forests were torn and tangled in a frightful manner.

Sugar-cane is our most important crop. Some of it was uprooted, some broken off at various heights, some damaged by water and the soft parts of the foliage stripped from practically all of it. In many cases it was necessary to plow out and replant. Broken canes sprout from the lateral buds and the sugar content is greatly reduced. The down and tangled cane is difficult to cut and the cost is increased.

Practically all the citrus fruits were blown from the trees and the ground was covered with fruits that would have been a joy to our northern markets. Many of the trees were uprooted or broken and many of the packing houses were partly or completely destroyed.

The coffee crop, which was just ready for gathering, was completely destroyed by the San Felipe and injured by the San Ciprián in some places. The coffee berries were whipped from the plants and the plants were damaged by the storm or by branches which were blown from the shade trees.

Banana plants were broken off near the surface of the ground and the fruit destroyed. Since it requires 12 to 15



MAPS SHOWING WEST INDIAN HURRICANES IN RECENT YEARS.

Map No. 1 (1926) shows ten storms; five of them were very severe and three of them were destructive. Storms No. II (July 24 to August 1) and No. VIII (September 15 to 22) struck Florida. No. X (October 19 to 22) caused heavy losses in Cuba and was felt in the southern part of Florida. Map No. 2 (1928) shows four storms. No. IV (September 11 to 17) was the San Felipe, which was very destructive in Puerto Rico and severe in Florida. Map No. 3 (1930) shows three storms. No. II (September 1 to 13) was very destructive in Santo Domingo. Map No. 4 (1931) shows five storms. No. I (August 10 to 18) caused heavy losses of life and property in Belize. No. V (September 8 to 15) was the San Nicolás, which was quite severe in Puerto Rico and Santo Domingo. Map No. 5 (1932) shows three storms. No. III (September 26 to 30) was the San Ciprián, which was very destructive in Puerto Rico. No. IV (October 31 to November 11) was very destructive in Cuba. Map No. 6 shows the centers of the paths of three hurricanes in Puerto Rico. No. I is the San Felipe, September 13, 1928. No. II is the San Nicolás, September 10, 1931. No. III is the San Ciprián, September 26, 27, 1932. The writer was located at A, which is just north of the town of Rio Piedras (B).

months for a plant to produce fruit, this source of food was greatly reduced.

The following figures taken from the United States Weather Bureau Reports may be of interest to the reader:

	S. Ciriaco	S. Felipe	S. Nicolás	S. Ciprián
Loss of life	3000	300	2	225
Lowest barometer at San Juan	29.23	28.81	29.17	28.95
Hurricane winds at San Juan for period of	3 hours	12 hours	2 hours	6 hours
Maximum wind velocity at San Juan	75 miles	150 miles	90 miles	120 miles
Maximum rainfall	23 inches*	29 inches†	5 inches	16.70 inches
Advance warning	19 hours	36 hours	40 hours	18 hours
Property and crop losses	$20 millions	$50 millions	$200,000	$30 millions

* Adjuntas records. † Maricao records.

A great tragedy usually has its comic features, and this has been true of the hurricanes that we have experienced. A few of them may be of interest to the reader. Some people took refuge in homes which they considered stronger than their own. The storm destroyed the houses of refuge and their own homes stood. A family took refuge in a closet. When the storm subsided they looked up and discovered that the second story was gone. A house was destroyed and the family took refuge in the children's play house, which was uninjured. A family went into the bath room; when the storm subsided they opened the door and found that all the house except the bath room had blown away.

It is impossible to understand the force of these wind storms without having passed through at least one of them. Therefore, we did not take the approach of the first one very seriously; but when we heard of the approach of the second, there was a feeling of dread rather than fear. Every one who has ever experienced one of these storms begins nailing boards over the windows and doors. If a window or door eaves in, the wind is almost certain to lift the roof unless a window or door is opened on the lee side well started, we lost the feeling of dread and were kept busy moving various articles so as to protect them from water that came through the roof and ceiling. As soon as wires began to break, the electric power was shut off and in the San Ciprián we were in total darkness, except for candles. Finally, the water came through in such quantities that it was impossible to keep the candles burning. By that time practically everything in the house had been moved into the dining room. We sat down and waited for the storm to subside.

The illustrations do not show the extreme damages resulting from the hurricane. The inconveniences following the storms are very great. Workmen open the main roads in a very short time, but the side roads and streets may be blocked for several days. The contents of the house must be dried as soon as possible, and this is not easily done, because showers of rain may be frequent and with little or no warning. It may be a month or more before the electric and telephone lines are working. But gradually conditions become normal and the love for the tropics returns.

WAVE TRANSMISSION AS THE BASIS OF NERVE ACTIVITY[1]

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WHEREVER we look in the world of matter and events outside ourselves we find that oscillations and wave motion have a significant, often a dominant, rôle. It is not, therefore, astonishing to find that waves play an important part in ourselves also. Let us discuss the nature of these waves.

Most of the well-known oscillations with which physics is concerned are a consequence of the reaction with one another of properties analogous to inertia and elasticity. A moving or a changing system tends, on the one hand, to continue in its state of motion because it possesses, for example, mass or inductance: even social, economic and intellectual changes are endowed with such characters of inertia, which keep them going when they have passed a true position of equilibrium. On the other hand, such systems, if they are to continue to exist, if they are not merely to be dissipated, must possess converse properties which tend to bring them back once they have overshot their equilibrium: such properties in physics are elasticity and electrical capacity, in finance and politics are fear and conservatism. These exercise a constraining force increasing with the displacement from equilibrium, and ultimately reverse the motion or change, and the same oscillation is repeated in the opposite direction.

There is, however, another type of oscillation, less commonly discussed in physics or mechanics but none the less well known in every-day affairs: that which depends upon a discharge taking place when some limiting potential or intensity is reached. For example, (1) water falling into a tank equipped with a siphon will come out in rushes whenever it rises to a certain level. Or again, (2) a population in which an epidemic of measles can not start because of the number of people in it who are immune, having had the disease already, will gradually become less immune as time goes on, and finally an epidemic, a wave, of measles will sweep through it. (3) A neon lamp with a parallel condenser, in series with a resistance and a source of electromotive force, will discharge at regular intervals, namely, whenever the potential difference across the condenser reaches a certain critical value. This type of oscillation does not depend upon inertia reacting with elasticity. Its essential nature is (a) that some state, some potential, some intensity, is built up by a continuous process, and the condition becomes less and less stable until one is reached in which discharge must take place, and (b) this discharge, once started, forms a path for itself by which (as in a siphon or an electric arc) further discharge is facilitated until what has been built up gradually has been broken down and the process begins again. This type of oscillator (sometimes referred to as a relaxation oscillator) is the one with which alone we are concerned in physiology.

Waves may be transmitted on the same principle in a system extended in space. An unstable state is gradually built up until at some point, either through an external agency or by some intrinsic process, discharge is begun, which starts and facilitates a discharge in neighboring regions which themselves discharge, and so a wave is propagated. Such waves will occur periodically if at some

[1] Address before the Century of Progress Meeting of the American Association for the Advancement of Science, June, 1933.

region the potential at which discharge begins is less than that finally attained by the continuous process of charging: they will require, however, an external agency (a "stimulus") to start them if the unstable condition, the limiting potential, is not attained spontaneously. Models of such waves will occur to all of you: their principle is obvious. I have emphasized it because the waves on which nervous activity is based appear to be of this type. All detailed theories of nervous transmission may well be wrong, but this general idea of it, involving building up and discharge, is almost certainly right.

One of the chief characteristics of living systems, particularly of animal ones, is "excitability"—the property of reacting to a small change in the environment, or even in the system itself, by a greater response. This excitability is zero immediately after a response has occurred: the cell or organ passes through a completely refractory stage: its potential is at first not yet high enough for any further discharge to take place. After the completely refractory phase, it passes into one in which its excitability is lower than normal, in which stronger provocation than usual is required to produce a discharge. Finally it returns to its initial state. This state may be one in which spontaneous discharge occurs, or, on the other hand, discharge may require what is known as a stimulus to start a path for it. In a single organ the final level may be above or below that of spontaneous instability, according to the circumstances. The greater the constraint on it the more quickly, in general, it reaches the level of discharge, the greater the frequency of the so-called "response." The time for the complete cycle from the absolute refractoriness following a response to complete recovery ready for further discharge varies greatly from one organ or cell to another. It may be measured in thousandths or in fractions of a thousandth of a second, it may be measured in seconds or even minutes.

An ordinary nerve trunk is a bundle of separate fibers along which messages are sent. The unit, the nerve fiber, is not normally spontaneously unstable, but it can be excited by various agencies, particularly by an electric shock, after which a wave starts off from the point excited and travels to the end of the nerve. Once the discharge has been started it persists and travels in space. If a nerve be injured persistent spontaneous discharge may occur. An ordinary muscle, which is a bundle of separate fibers which contract and do mechanical work, is not spontaneously excitable, though it also can be stimulated by various agencies; it is easy, however, by a slight change in the salt content of its environment to render it state unstable, so that regular oscillatory discharges take place in it; these can be recorded electrically and result in visible twitchings of the fibers. The heart muscle, on the other hand, has naturally an inherent rhythm of its own: after a beat it is at first completely refractory, then for a period it can be excited, *e.g.*, by an electric shock, finally it beats again of itself. Something in it is gradually restored, until a potential is reached at which discharge must occur. This restoration is quicker in one region than in another, and since the discharge once started is propagated as a wave, the rhythm of the heart as a whole is set by that of the region in which restoration is quickest. All parts of it, however, have the same property of spontaneous discharge, and even an isolated portion of heart muscle will beat of itself, though more slowly than when attached to its natural pace-maker. If its mechanical tension be diminished enough the spontaneous beats may disappear; the lack of mechanical constraint somehow raises the level at which instability is reached and at which spontaneous discharge occurs.

It is necessary sometimes for a physiologist, as Rutherford was once heard to say, to make a noise like a physicist. Physics is not indeed the only, or even the chief, way of approaching physiological problems, but it has among its advantages that of providing at such a conference as this a language by which other people, for example, engineers, physicists and chemists, may be introduced to physiology. Through no fault of their own, no doubt, many people, people of high scientific standing, have never had any experience at all with that subject. They often have very absurd ideas about it. They do not perhaps go so far as the lady who, to a doctor trying to explain to her what was wrong with her, made the appeal, "Don't, Doctor, don't—I like to think I am lined with pink satin." But they are apt nevertheless to picture the inside of the body, if not as pink satin, at least as beyond the range of reasonable scientific method. If, as I hope, there are a few engineers, physicists and chemists here, I would reassure them: physiology, and in particular that of the nervous system, is an experimental science like any other: no doubt it requires great experimental skill, but that makes it the more amusing: it is complex, but not beyond the wit of man to investigate: its complexity depends partly upon the difficult nature of its experimental unit, the single living cell, partly upon the fact that most of the effects which can be observed are due to the action and interaction of very many of these units.

The nerve fiber in which the waves run is part of a nerve cell: the central part of the nerve cell usually lies in or near the nervous system: the fiber—the axon—runs out to the organ, muscle, gland or sensory ending, with which it is connected. The fiber is a fine thread of protoplasm, a few thousandths to a few hundredths of a millimeter in diameter but often of considerable length. The velocity with which waves are propagated in these fibers may be anything from 100 meters to a few centimeters per second. In our own motor or sensory nerves the speed is somewhere near the upper of these limits.

The messages which pass in nerve fibers can be detected by various means apart from the response, *e.g.*, movement or sensation—which they provoke. The chief of these depends upon the fact that each impulse has an electrical accompaniment, which, owing to recent improvements in electrical technique, can be easily and accurately recorded. Not only, indeed, can we see nerve waves chasing each other along the screen of an oscillograph, not only can single impulses in single fibers be recorded photographically, but we can even listen on a loud speaker to sensory impulses caused, for example, by gentle pressure on the toe of a cat. As Adrian says, there would be no particular difficulty in demonstrating the potential change in a frog's nerve fiber as an audible signal on the radio. The power in the input circuit would be of the order of 10^{-14} watt, the transmitter might radiate 50 kilowatts, five million million million times as much. It would, as he adds, be a sad confession of failure if with these resources we had learned nothing fresh about the working of the nervous system. As a matter of fact, we have.

In, and in connection with, the living body itself as part of the complex telephone arrangements of the central nervous system, this electrical sign of nerve activity is the chief means by which in the last few years the subject has grown so fast. Other signs, however, there are, and the investigation of these has led to considerable advance in knowledge of the physical nature of the nerve wave itself. For example, when a single impulse travels down a medullated nerve there is an immediate rise of temperature of the order of 10^{-7}° C. (one ten millionth of a degree). This represents a liberation of energy, small, indeed, but

perfectly definite, of about 4 ergs per gram of nerve. A single fiber one hundredth of a millimeter in diameter, if it weighed one gram, would need to stretch about 10 kilometers. Thus, in sending a single nerve impulse 10 kilometers, the amount of energy immediately set free would be about 4 ergs. One gram-calorie would send it 10^8 kilometers, about half the distance to the sun. Clearly, communication by nerve fiber is not very expensive!

Let us remember, however, the number and variety of nerve waves involved even in ordinary activity. Nothing perhaps can better illustrate nervous action than a short discussion of the nature of muscular skill. What does a skilful muscular movement feel like to the performer himself: how does he control it as he proceeds: how does he learn it: how does he remember it: how does he reproduce it? We know that when any particular task is undertaken, any particular movement made, a stream of messages is sent out in appropriate sequence, most accurately adjusted, along tens of thousands of nerve fibers to the millions of muscle fibers that carry it out. We may imagine as a first and rough approximation that the brain and nervous system contain a carefully catalogued set of gramophone records, each ready to be taken out and turned on when required. If we come to a hurdle the high jump record is required: when we come to a ditch, the long jump record. In a sense this simple idea is true. Our behavior is largely composed of ready prepared gramophone records, called up and set going by the appropriate stimuli, and our skill in movement depends very largely on the degree to which we have learned to make it automatic. Nearly everything we do is partly unconscious. When we walk down the road we just give our nervous system general instructions to walk. We don't set out in detail how every muscle shall move, how every unevenness is to be overcome, we probably don't even know. Our movements, therefore, are largely automatic, they consist largely of gramophone records, prepared beforehand by instinct or by training and ready instantly to be turned on. On the number of the actions which we have learned to make automatic, on their coordination one with another, on the fineness and accuracy with which they are adjusted to the stimuli which evoke them, depend largely the skill and efficiency with which we work. True as this is, however, it represents only a very limited aspect of the truth, because it neglects one half of the nervous system, the half that tells us what we are doing and enables us to adjust it as we go, the half by which we really remember what muscular movement is like.

Take the simplest possible movement. Try to bend your finger slowly at a uniform constant speed. You will find that it does not really move uniformly but in a rapid series of jerks. A record may be made in some way, for example, by connecting your finger to a lever writing on a smoked drum, or by photographing a beam of light reflected from a little mirror stuck upon the knuckle. The record allows the jerks to be counted. If the jerks be few they will be large and the finger will seem shaky; if they be many they will be small and the finger will seem steady; the most skilful person, and the one with the steadiest hand, is he who checks and controls his movements most frequently and rapidly. In all our movements the mechanism "hunts" to find the right adjustment. The smaller the amplitude of the "hunting" the more skilful we are.

How is this done? From all the moving parts of the body, muscles, tendons and joints, a system of nerves runs inwards carrying information about what is happening in those moving parts. These messages are started off by end organs, excited by movements in the tissues where they lie. Muscles are ar-

ranged in pairs or groups, and any given movement is due to the cooperation or antagonism of a whole set of different muscles. When you sail a boat you don't just set the sails and tie up the rudder: you watch the wind, you adjust the sheet, you keep your hand upon the tiller, there is a continual interplay between the wind, the sea, the sails and the steering. In the case of bodily movement the nervous system is the steersman, who has to compound all the messages—the nerve waves—he receives to form one general impression on which to act. When a given muscle shortens, its antagonist has to lengthen. But notice: the antagonist does not let go all at once: if it did, the result would be like letting the sail out with a crash: it pays out gradually, in little jerks, each element in the contraction of one muscle provoking reflexly an element in the relaxation of its antagonist. This interplay is going on continually, one muscle hauling in a little, another paying out, so guiding and controlling the movement, keeping it as smooth, as accurate and as well coordinated as may be. This continual reaction between muscles, nerves, end-organs and central nervous system is the physiological basis of muscular skill, and on its smooth and efficient working depend many of the things that mankind finds worthy of accomplishment.

I will not venture inside the nervous system itself. That would require not a lecture but a series of lectures to discuss. You must think of the nervous system as a vast exchange, in which incoming messages from all corners of the body are sorted, assessed, correlated, recorded, in which the response most necessary in view of all the circumstances is worked out. The automatic telephone exchange, the control post of the automatic traffic signal, both carry out this function in respect of a single purpose: the central nervous system does it in respect of all possible purposes. I can do little more in this lecture than refer to the messages themselves, those which come in, those which go out, those which—in all probability—circulate within the exchange itself. These messages are all of one kind, and before we can begin to understand the nature of nervous action it is necessary that we should know something about the unit on which the whole of the mechanism is based, the wave which travels in the thread of living protoplasm.

The ending of every sensory nerve fiber has a specific kind of sensitivity, to touch, to pressure, to heat, to cold, to light, to vibration, as the case may be, and its manner of reacting also is specific. Certain properties, however, are common to all. Of these the most significant is the cycle of refractoriness and returning excitability which follow. All these organs are "relaxation oscillators" of the type I referred to earlier. The specific stimulus is the external cause or constraint which alters the level at which spontaneous discharge takes place: the stronger the stimulus, the lower the level, the more frequent the discharge. Some of these organs "adapt" to a constraint or stimulus. The hand put in warm water feels it warm, but in a very short time the organs sensitive to warmth adapt and no sensation is experienced. Similarly with touch. With sight there is some adaptation but not to the extent of complete lack of sensation: with the organs which tell us the state of tension in our tendons there is little: with sound there is practically none. The mechanism of this adaptation, this change of level of discharge, is not understood, but its existence is an essential part of our being. The level of discharge of some of our oscillators is not constant under a constraint but gradually rises; with these the frequency of discharge diminishes; with others the level remains constant for long periods and so the same frequency persists.

One limit to the nerve fiber and the wave that travels in it as a means of reporting to the nervous system events occurring outside is that it can not react (in the case of man) more than about 1,000 to 2,000 times per second and at that speed only for a short time. Two of the most important stimuli are those of light and sound: *light* waves have a frequency of the order of 10^{15}, utterly beyond the frequency of the nerve fiber; to limit appreciation of *sound* below 1,000 to 2,000 waves per second would greatly interfere with its quality. Now if a single nerve fiber, with no specific properties, is stimulated at a frequency higher than it can follow, two things may result: (1) It may respond at the highest submultiple of the frequency which it can follow, *e.g.*, $\frac{1}{2}$, $\frac{1}{3}$, $\frac{1}{4}$; (2) it may fail to respond at all. It will do the first if the frequency is not too high: the second if it is. It is well known that very high frequency stimuli (say 100,000/sec.) have no excitatory effect at all, even when of a strength many times greater than that of an ordinary alternating current. Sparks may be drawn from a man's hand with no more sensation than that of the heat produced by the current. This is commonly attributed to the fact that high frequency currents tend to travel on the surface of a conductor: the explanation will not hold, for two very good reasons: (1) the sensitive end organs are largely in the surface, so the effect should be greater, not less, and (2) with the high specific resistance of living material the skin effect is negligible, even at frequencies hundreds of times greater than those at which the excitatory effect disappears. The absence of stimulus is probably due to an electrical capacity existing at the surface of the excitable tissue, which prevents a potential difference from developing and a current from running across the surface until the capacity is charged. Whatever the explanation, the fact is a very obvious one: a nerve does not respond at all to stimuli of high frequency, which is probably why the limit of our hearing is about 30,000 waves per second. Below this limit, although an auditory nerve fiber is incapable of following say 10,000 vibrations per second, it can follow some submultiple of it, say 1,000 per second, and since the different fibers will very soon be out of phase with one another one tenth of them will respond to every cycle and the brain will in fact receive 10,000 volleys of waves per second. A number of nerve fibers can in this way respond to a frequency to which the individual fibers can not conceivably respond—a fact which has recently been verified by placing electrodes upon the auditory nerve and leading off to a loud speaker, when the ear and nerve together act as an efficient microphone, recording frequencies which no single fiber could conceivably follow.

In the case of light nothing of the kind occurs, nor presumably could it with electromagnetic waves except of very great wave-length, and no specific receptor for these exists. In the case of light a chemical reaction occurs between the physical factor—the electromagnetic vibration—and the response evoked by it. Unlike the case of sound, there is no direct numerical relation between the wave-length of the light and the response recorded. The stimulus is turned into chemical code in the retina, and forwarded by waves of various frequencies and in various fibers to the brain. There it is interpreted. The ear is capable of responding to frequencies from 50 to 20,000 or so, a ratio of 400 to 1, a matter of nearly 9 octaves. The eye responds only within one octave. The difference presumably is that the nervous mechanism is capable of transmitting the response to the separate sound waves as separate groups of conducted nerve waves to the brain; the light waves have to go by a roundabout way *via* a chemi-

cal reaction and a code. What a wonderful world of color we should have were our eyes sensitive to nine octaves!

One of the greatest achievements of physiology in the last years has been the proof by Adrian and his colleagues that the only way in which a sensory nerve fiber alters its response, as the strength of the stimulus is altered, is by a change in the frequency of the waves which it forwards to the central nervous system. I may have disguised my meaning by a too careful choice of words, but I fear the wrath of my psychological friends if I dare to hint that the sensation due to a stimulus is measured by the frequency of the nerve waves which it produces. The total effect of a stimulus depends upon three factors: the number of fibers which, by means of their end organs, it affects: the frequency of the waves evoked in each of these fibers: and the state of the nervous system, as affected by other stimuli simultaneously occurring, and other such factors. If I am to keep outside the central nervous system I must never come to sensation at all, but refer only to the number of separate nerve units reacting to a stimulus and to the frequency of the reaction of each. The waves in these fibers are, however, at least the physiological basis of sensation.

At the other end of the scale is the response of muscles and glands by which the purposive reactions of the nervous system are effected. Here again waves in nerve fibers are the means by which communication is effected and orders despatched. These are waves of the same identical nature as occur on the sensory side, but waves of the type occurring in nervous conduction can never cross one another, one-way traffic is necessary, and separate motor nerve fibers are provided. Here let me make a digression for a moment. A wave leaves a discharged region, a refractory region, behind it; for the same reason as waves can not follow one another with less than a certain interval two waves can not cross—each comes into the discharged region of the other and both are wiped out. Curiously enough, however, all tissues capable of conducting these waves are in fact able to do so equally in either direction: though in normal life, except in special instances (and perhaps in the central nervous system itself) they never do. Sometimes tissues are so arranged that a wave can take on a circus movement and go on running round—chasing its own tail—more or less indefinitely: this curious phenomenon, discovered in the heart of a marine animal, is the basis of an important clinical disorder of the human heart. In the nerve networks of some primitive animals, and in those of the vegetative organs of higher ones, the same type of circus movement of nerve waves probably occurs. Mainly, however, one finds waves which begin and end in a single stretch of conducting tissue.

These waves, which are orders to the effector organs, reach in general three types of reacting cells—voluntary muscle cells, involuntary muscle cells and gland cells. Their passage to the voluntary muscle cells is so rapid that one tends to regard it as of the same nature as conduction in the nerve itself. In the other two it may have as intermediary, at least in certain instances, the liberation of a chemical substance—*e.g.*, acetyl choline or adrenaline—which slowly produces a more prolonged response. The manner and mechanism of conduction from nerve to muscle fiber is still disputed, but there are some interesting facts to record.

Let me first, however, refer to muscle and its response. The elementary unit of muscular contraction is the twitch—a rapid wave of shortening—lasting only a few hundredths of a second in a human voluntary muscle. All ordinary contractions are made up by the fusion of such twitches: and the strength of a

contraction depends upon the number of fiber groups reacting and the frequency with which these react. A maximum effect is made with 50 motor impulses per second. This frequency can, as a matter of fact, be rather easily seen in a muscle by recording either its mechanical or its electrical response in a strong contraction. In a weak contraction the fibers are reacting at a lower frequency and out of phase with one another, so not much is seen. In a strong contraction groups of them seem to fall into phase by some kind of resonance in the central nervous system. Normally the impulses pass from nerve to muscle without hindrance. In some conditions, however, a block is interposed across which the waves can pass only with difficulty, if at all.

Such a condition may exist in a normal muscle after severe fatigue: experimentally it is best seen by poisoning with the South American arrow poison, curare. In this state the first effect is that only low frequency impulses can be transferred from nerve to muscle: the next is that complete paralysis occurs. The mechanism of this paralysis is disputed, but one curious and interesting example of its occurs in man. A disease exists called *myasthenia gravis,* in which the patient is incapable, for more than a second or two, of making any considerable effort. If the ulnar nerve in the human arm be stimulated with a series of electric shocks the muscles working the fingers are thrown into contraction. In a patient with myasthenia two things may happen. If the shocks are of rather high frequency the response rapidly fades away. If they are of low frequency the response is nearly normal. When failure to respond to a higher frequency has occurred, transfer to a lower frequency gives the full response again. Here apparently there is an abnormal condition in nerve or nerve-ending which is probably the cause of the characteristic sign of the disease. Few physiologists are so sour that such a sudden contact with clinical medicine does not give them a thrill of pleasure. Such contacts, seemingly by chance, provide even the most academic science with its relation to reality.

Apart from the ordinary motor and sensory impulses to which I have referred, a multiplicity of mechanisms exists all over the body, depending on the use of impulses in nerve fibers for coordinating function. The lungs, for example, expand and contract rhythmically. This depends partly upon a genuine rhythmic function in the center—a spontaneous discharge of waves from certain cells. On this, however, a major control is exerted by impulses sent from end organs in the lungs themselves. The movement of the lungs excites these organs which discharge waves along fibers to the center and so check and control and limit the contraction of the diaphragm. Normal breathing is a balanced movement consisting of the continual interplay and adjustment of impulses going to and from the center. Another such mechanism exists in the carotid sinus by which the pressure and composition of the blood cause impulses to be discharged to the centers by which adjustments of these are effected. With the high power of modern electrical instruments there is scarcely any corner of the body from which such messages can not be found pouring out—and listened to with loud speakers, recorded with oscillographs.

You probably have heard the story of the little boy who wanted to know how animals came into existence and had been told by his mother that God had made them. "And did God make flies, too, Mummy?" "Yes, dear." "A fiddling job making flies." If he could have connected loud speakers and oscillographs on to the nerve cells and nerve fibers of a fly and heard and seen the

amazing complex of wave motion, roaring backwards and forwards even in that small creature, he would have realized that "fiddling" was far too mild an adjective. I do not know how many motor and sensory medullated nerve fibers there are in a man, but let us guess. Assume that they weigh altogether 100 grams, that they have an average length of 50 cm and an average diameter of 14 μ. This would give about a million of them: I expect this is an underestimate. Let us think of a man running in a quarter mile race, exerting himself to his utmost. I think we may admit an average of at least 10 impulses per second to each of the fibers; total, 10 million waves per second. This hurricane of coordinated impulses is raging in our runner. Even at rest I suppose we may allow him one twentieth of this, half a million per second. Each of these impulses could be picked up and recorded or made audible by modern electrical technique. Each wave has the same general characteristics. Each is a reasonable and intelligible thing. The properties of a gas depend upon the average behavior of its molecules, but that is governed by statistical rules. The properties of a man depend upon the total behavior of his nerve impulses —but these—although so many—are coordinated and adjusted. Truly, as David said, we are fearfully and wonderfully made.

PLANT PATHOLOGY AND THE CONSUMER

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Now that "Mankind at the Cross Roads" and the various less thoughtful tracts which threatened us with early starvation have passed into the shadow of the greatest food surplus of modern times, it is no longer possible for the plant physiologist or pathologist to justify his activities on the simple grounds of the necessity of saving the human race from hunger. This may then prove a favorable time for a reexamination of the practical results of plant disease control measures in this country during recent decades. At present there is a tendency for the plant pathologist to apologize for his profession. His apologies cover, of course, only the practical phases of his work and not the fundamental investigations, the results of which form international assets and which in our day need neither justification or apology. Obviously, if all the professional plant pathologist has to offer as a practical reason for existence is still further expansion of production, he is entitled to a prolonged holiday, and unless he can demonstrate the contrary he will probably get one.

It may be conceded freely at the outset that it is a general conception that the chief aim of applied plant pathology is the production of larger crops and that the benefits of plant disease control go to the producer of food rather than to the consumer. A somewhat more careful examination of the work of the plant pathologist shows that he is fully as much concerned with quality as with quantity of product and that the practical results of his studies are in many cases of even more benefit to the consumer than to the producer. The popular misconception referred to above is due in part, of course, to the great interest in foodstuffs taken by the agricultural population and the very great ignorance regarding the food supply common among city dwellers. It is also partly due to ill-advised propaganda.

It would be easy to demonstrate that, in general, technical improvements in agriculture which increase production actually redound chiefly to the benefit of the consumer. This point of view is adequately summarized in the report of the Secretary of Agriculture for 1931 (p. 25):

> Technical progress has increased farm productivity tremendously in the last 15 years, but the benefit has gone largely to the consumers. Farming has been industrialized and mechanized. It has used science, decreased its production costs, and increased its output, without finding either profit or security in the process. It has made two blades of grass grow where one grew before, only to find the second blade depressing the price of both.

The purpose of the present paper is not to discuss this general proposition but to point out a few of the specific ways in which the results of plant disease studies have been of benefit to the consumer, have indeed functioned directly as "consumer's research," if I may borrow the name of an active and worth-while modern organization.

Timber Treatment

Direct benefit to consumers from the investigations of plant pathologists is illustrated in the success of preservative treatments in prolonging the life of timber used out-of-doors. Methods of treatment as well as types of preservatives have been improved in recent years, but even those available twenty years ago were of measurable benefit.

Fig. 1, taken from the report of the twenty-eighth annual meeting of the

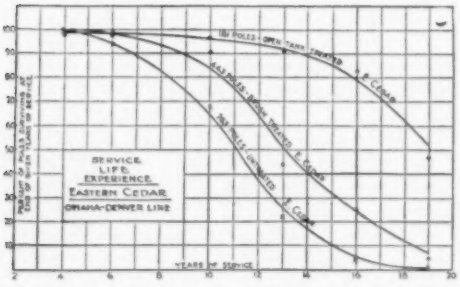

FIG. 1. SERVICE LIFE EXPERIENCE OF TREATED AND UNTREATED TELEPHONE POLES ON OMAHA-DENVER LINE.

American Wood-Preservers' Association, shows the results of actual experience under field conditions with untreated telephone poles as contrasted with those treated by two different methods. It will be noted that at the end of 19 years practically all the untreated poles had been replaced, while half of those having the best treatment were still in service.

Something has been accomplished in the study of the diseases of growing trees and the control of certain forest nursery diseases, but no progress in this field has yet been observed which is at all comparable to this achievement of doubling the useful life of poles. In considering these results it should not be forgotten that, measured either in terms of human labor or dollars, the telegraph pole or railroad tie ready for use is a much more costly article than the growing tree. The situation is well summed up by Colley:[1]

> To the consumer, decay in forest products means more than the loss of the actual wood which has become rotten. It means replacement costs for lumber and labor, idle factory space and abortive attempts to use substitute materials in places where nothing can ever have the utility of wood. The individual purchaser bears most of the expense.

[1] *Science*, 61: 107–109. 1925.

While the benefits from modern timber treatment are most readily available to large organizations which can treat their own material, it is already possible for the individual householder in certain parts of the country to purchase small lots of treated lumber, and the supply will increase as demand grows.

THE PROBLEM OF DECAY OF FRUITS AND VEGETABLES IN TRANSIT

The losses from decay of fruits and vegetables in transit and on the market fall directly on the food consumer, although like many of his other taxes he pays them unconsciously. The price which the consumer pays must in the long run cover the losses of transportation and sales agents. Any reduction in such losses is a direct gain. Losses in "perishables" have been notoriously high and very difficult to reduce. This is well shown by recent reports of the freight claim division of the American Railway Association, a unit especially charged with the task of reducing the cost of "loss and damage" in railway shipments. The subjoined table, for which I am indebted to Mr. Lewis Pilcher, secretary of this division, shows both the high degree of success attained in reducing "loss and damage" in all

TABLE I

ANNUAL "LOSS AND DAMAGE," AS REPORTED BY FREIGHT CLAIM DIVISION OF AMERICAN RAILWAY ASSOCIATION

Year	All commodities	Fruits, melons and vegetables (only)
1921	$96,730,376	$13,898,081
1922	48,084,995	8,830,192
1923	49,540,377	10,098,402
1924	48,262,543	12,058,603
1925	38,772,097	8,851,871
1926	38,187,315	8,293,529
1927	38,713,059	9,207,554
1928	36,557,243	9,406,578
1929	37,432,966	10,366,134
1930	36,239,640	11,792,569
1931	25,868,485	9,150,161

commodities and the relatively great difficulty of affecting that portion which includes fruits, melons and vegetables.

The reduction in the total from over 96 million in 1921 or even 48 million in 1922 has been marked and on the whole continuous. The amount so paid in 1931 was less than 26 million. The loss from perishables, on the other hand, was higher during the period 1929 to 1931, inclusive, than in the preceding triennium or even from 1921 to 1924. During the first five years, 1921 to 1925, the cost of "loss and damage" from fruits, melons and vegetables constituted approximately 19 per cent. of the total. During the five years, 1927 to 1931, it made up over 28 per cent. of all "loss and damage." In spite of this somewhat discouraging showing, something has been accomplished in those lines where most work has been done.

Reduction of Losses to Tomatoes and Strawberries in Transit 1922 to 1930

Both tomatoes and strawberries have long been recognized as being very subject to decay in transit and on the market, and although the field diseases of the two crops are different, the decays which occur in transit are in some ways comparable. An important part of the loss in each crop is due to a species of Rhizopus, which enters through wounds and produces the characteristic decay usually known as "leak."

Recent summaries of losses in transit, compiled from the reports of the food products inspection service of the Bureau of Agricultural Economics, make possible a rough comparison of the losses due to decay in transit from certain Southern states having long hauls to market. These reports are based solely on market inspections by unprejudiced observers and, therefore, furnish a type of information not obtainable from the usual sources of plant-disease reports or crop-loss estimates.

The figures for both tomatoes and strawberries deal with those producing states having the largest number of market inspection certificates. In the case of strawberries the certificates studied included shipments from Alabama, Arkansas, Delaware, Florida, Kentucky, Louisiana, Maryland, Missouri, North Carolina, Tennessee and Virginia. These eleven states had in 1930 over 113,000 acres of strawberries, which represented almost two thirds of the "commercial" strawberry acreage of the country. Figures for tomatoes are based on inspection certificates from California, Florida, Mississippi, Tennessee, Texas and Mexico. The five states considered, namely, California, Florida, Mississippi, Tennessee and Texas, had in 1930 somewhat over 109,000 acres of tomatoes grown for the fresh fruit market. This represents about two thirds of the commercial acreage reported as grown for the fresh market in the United States.

Using as a measure of loss what Dr. D. H. Rose has called "a disease index," namely, the sum of the percentages of all the diseases noted, and comparing the four-year period 1923 to 1926 with the four-year period 1927 to 1930, it is evident that there has been a reduction

TABLE II

Comparative Losses in Transit of Tomatoes and Strawberries from Certain Southern States as Indicated by Inspection Certificates

Year	Losses in transit	
	Tomatoes	Strawberries
1922	12.8	8.6
1923	11.7	9.0
1924	9.5	5.2
1925	9.1	4.2
1926	9.8	4.3
1927	8.9	4.1
1928	8.1	3.0
1929	7.2	4.6
1930	7.7	3.4
1923–1926	10.0	5.7
1927–1930	8.0	3.8

of losses during the latter period in both these crops.

If these percentages look small, it should be remembered that the annual commercial strawberry crop of the United States varies from 200,000,000 to 300,000,000 quarts, and the commercial crop of tomatoes usually runs well over a million tons. Among the factors which may account for this difference, improved handling methods and improved refrigeration seem to be the most probable. There have been few changes in varieties or in cultural methods, but much educational work has been done which has tended to improve handling methods, and there have been mechanical improvements in refrigeration and equipment.

Such gain as has been made in tomatoes and strawberries has come through the gradual improvement of handling and refrigeration directed toward the control of certain rot fungi, and the figures here given are derived from a number of widely separated producing areas. More striking results are shown where direct control methods have been applied in areas of intensive cultivation of a single crop. As an example of a specific disease control measure which has become part of regular commercial practise to the advantage of the consumer, the control of apple scald may be cited.

Apple Scald

Scald has long been recognized as a serious disease of apples during the latter half of the storage season. The disease was made the subject of much study, and finally there was developed a simple and easily applied control method—that of packing box apples in oiled wraps and barrel apples in shredded oiled paper.

The results of this treatment in apples shipped from the state of Washington are graphically shown in Fig. 2, compiled from the inspection certificates

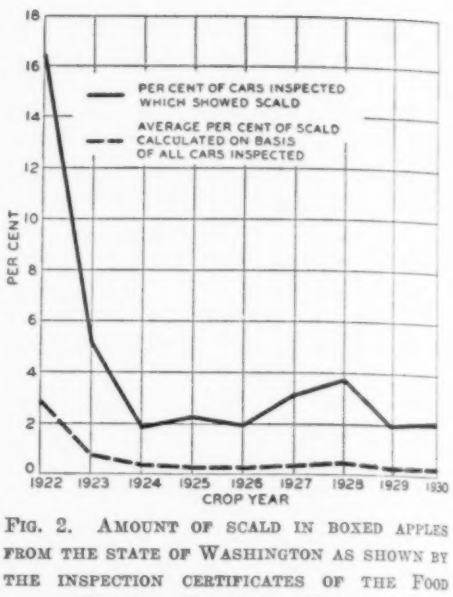

Fig. 2. Amount of scald in boxed apples from the state of Washington as shown by the inspection certificates of the Food Products Inspection Service.

of the food products inspection service, Bureau of Agricultural Economics, U. S. Department of Agriculture. A small proportion of the Washington apple crop was packed in oiled wraps in 1922, a much larger amount in 1923, and by 1924 the method had been generally adopted. Since that time it has continued in popularity and has become a part of regular commercial practice in that region. In 1922, a year in no way exceptional in the incidence of scald, the percentage of inspected cars showing scald was 16.4. This fell to 5.3 in 1923, and in the succeeding years has averaged approximately 2.5, which is somewhat less than one sixth of the amount for 1922.

Plant Pathology and the Ultimate Consumer

For those whose ideas of "consumer" is even to-day restricted to the "ultimate consumer" who actually eats the food, wears out the floor boards or talks through a telephone, as well as for those

who are not ready to concede that under present conditions reductions in production costs reach such ultimate consumers, it may be worth while to point out that many losses, preventable or reducible by methods developed by plant pathologists, fall largely and inevitably on this very ultimate consumer. The fact that the plant pathology of the kitchen has been little discussed or emphasized has, perhaps, obscured the fact that here are met many of the most serious losses from plant diseases. It must be obvious that for a given percentage of loss by disease in fruits and vegetables the consumer's loss is actually greater than the producer's for the simple reason that the individual unit is so much more expensive. That is, the consumer's apple is the producer's apple plus the cost of picking, packing, shipping, storage and handling, as well as sales costs and profits.

In addition to this it should be noted that the actual percentage of loss in the home is often much larger than the losses usually recorded either in field or in transit. This is especially true of decays of fruits and vegetables. A conspicuous example of this is the apple scald discussed above. Serious as the losses appeared to be to those who produced or stored apples they were relatively much more serious to the housewife who in peeling a badly scalded apple for cooking or eating threw away one fourth to one third of the otherwise edible portion.

The same thing is true for such preventable diseases as potato scab, which apparently does not affect the vigor of the growing plant or the total yield and may well pass for a mere surface blemish to unsuspecting housewives but results in a real loss in the quantity of food available to the (in this case the literally) ultimate *consumer*. This relation holds, even more strikingly, for decays of the more perishable fruits. For example, a loss of 10 per cent. in a car of strawberries would be considered very large, indeed, but in a fairly large proportion of boxes of strawberries the purchaser finds it necessary to throw away more than 10 per cent.

It was admitted in the opening paragraphs that neither the professional plant pathologist nor the consumer ordinarily realizes that the practical benefits of plant disease studies go in large measure to the ultimate consumer. This failure to recognize the closeness of the relation has, of course, no bearing on its reality, but may well hinder its fullest development. Somewhere in his collected legal papers Justice Holmes develops the philosophy that men may well do most for the public good under "the illusion of self-seeking." He insists further that, "We all, whether we know it or not, are fighting to make the kind of a world that we should like." My own feeling is that the plant pathologists of this country are working, whether they know it or not, largely in the interest of the consumer. And further, that it would promote better relations all around and more effective progress if the fact were generally understood.

CAUSALITY IN THE PHYSICAL WORLD

By Professor R. B. LINDSAY

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HUMAN life is proverbially uncertain; it is commonly said that in this world we are sure of nothing but death and taxes (one might almost say further, an increase in taxes). In sharp contrast, the inorganic universe in which we live and which is the object of our senses has been commonly assumed by most to be governed in all its workings by quite definite and immutable laws which, like those of the Medes and the Persians, "altereth not." No matter how disorderly mere man shows himself, the large scale universe at least is on the side of law and order. The actions of a politician may be decidedly unpredictable, but for nature the great principle that every effect has a definite cause seems to be still on the job. At least this has been the common feeling up to rather recent times. In the past few years, however, there have been some very disturbing reports from the laboratories and the studies of physical scientists. The mystic but somewhat discouraging word "probability" begins to be heard more and more frequently; more and more frequently the Sunday supplement cartoonists are called upon to produce pictures of chaos to illustrate the popular accounts of the latest developments in theoretical physics. We learn that the greatest authorities are convinced that the watchword of nature is no longer "cause" but "chance," and more disturbingly still, not merely the kind of chance which the life insurance company exploits to the advantage of all its policy-holders, but also the kind of chance that is displayed in the speculations of the stock market. We are presumably asked to adopt the view that nature is in the last analysis the plaything of a gambler, that nothing in the universe is really predictable.

Now the question which I wish to discuss in the present article is simply this: What is the justification for this new view? Is the situation after all as serious as it sounds? And is it not possible that the popular accounts may be leading to an unfortunate misunderstanding of the whole problem? Of course one who desired to be only moderately cynical might say at once that all attempts to popularize science lead to misunderstanding, and hence that my attempt will probably merely lead to "confusion worse confounded." I can only hope that this result, to use the new jargon, will not follow with certainty but merely with a certain degree of probability.

Before one can have any appreciation of the meaning of causality in physics, it is necessary that one shall understand just what the physical scientist does, what his business is. It may be objected that this is a long story. That is true, but a brief survey seems essential. To state what science (or, in particular, physical science) is in words of one syllable is, of course, not easy. As an introduction consider the following, a slight modification of a parable of the philosopher Schopenhauer: "Two Chinamen traveling in Europe went to the theater for the first time. One of them did nothing but study the stage machinery, and he succeeded in finding out how it was worked. The other tried to get at the meaning of the play in spite of his ignorance of the language. In the former you have the physical scientist, in the latter the philosopher." This is not intended to be at all derogatory to the philosophers. But no one can fail to

see the profound difference in method that is here implied. Both philosopher and scientist seek for an understanding of the experience of mankind, *i.e.*, the sum total of our sense-impressions of all kinds; but while the philosopher (at any rate in the past) has sought to appreciate experience as a whole in what may be called its fundamental aspects, the physical scientist tries to abstract from the totality of experience certain small sections which he thinks he has some hope of describing in such detail that the result holds meaning for himself and other persons with similar interests. It is commonly said that the task of science is to explain all natural phenomena, but it is well to recognize that the scientist here uses the word explanation in a very special sense, namely, that better expressed by the term description. It is not the function of the physicist to answer the question why experience is as it is, but rather how do things actually go. The latter is a less ambitious program than the former. Perhaps that is why it has proved so much more successful during the three or four hundred years during which it has been pursued. Many well-intentioned and enthusiastic people have indeed attempted, for example, to explain why the law of gravitation holds, that is, why every particle in the universe should attract every other one with a force inversely proportional to the square of the distance between them. They have done this by the invocation of all kinds of cosmic urges and mystical forces. However, it is safe to say that all this has proved worthless for the development of physical science as compared with the simple assumption of Newton, expressed in mathematical form. For the latter, when combined with the principles of mechanics, has yielded the whole of celestial mechanics, one of the crowning achievements of the human mind. Of course, I must hasten to add that there have been theories of gravitation, some of which, like that of relativity, will undoubtedly prove of significance for physics. These, however, are in quite a different category from "crank" literature, as a close study of the meaning of a physical theory will show.

If, then, the task of the physical scientist is to construct a description of certain limited portions of experience, we ought to say a few words about the character of this description, the method by which it is made. In the first place, we must note that the data of physical science are obtained almost exclusively from experiment or controlled sense-perception. Passive observation, stimulated by idle curiosity, may have been good enough for ancient times but has long since ceased to suffice: the physicist now insists on abstracting from the totality of experience a small domain for specially intensive investigation; he has in his mind certain ideas which relate to this domain and which lead him to frame definite questions; finally he decides to go through a well-defined course of activity by performing some carefully thought-out operations in the laboratory. This operational idea is closely connected with the notion of measurement. It is here that there enters into science the highly sophisticated mode of thought called mathematics with its attendant symbolism, of which number is the most important form. Every experiment in physical science in which measurement plays a rôle (and these are in the overwhelming majority) reduces essentially to an operation involving the observation of the coincidence of a point or pointer with a mark on some scale, or the comparison of sets of such coincidences; the symbolic expression of the observation is made by means of numbers associated with the marks. We think at once of such illustrations as measurement of temperature with a thermometer, of electric current and electromotive force by means of meters, of mass by a balance, or time by a clock,

etc., etc. In every case there is a scale and in every instance we are interested in the position of a pointer on that scale: the result we insert in our note-book is a number representing the position of the pointer on the scale or what Eddington has called a pointer-reading, a now justifiably famous term.

The brevity of these remarks is, I fear, rather disconcerting, but at any rate it is evident that some rather fundamental matters are involved. The use of scales and a clock at once introduce the notions of space and time and commit the physicist to some kind of view with regard to these categories. More important still, perhaps, is the emphasis on the fact that the description of physical experiments is carried out in terms of number symbolism. This is an extremely significant state of affairs. Its adoption has colored the whole development of physics, so that now physics without the symbolism of mathematics appears meaningless. Of course the symbolic method has far transcended the elementary use of numbers. There is hardly a branch of mathematical symbolism which has not found valued use in physics. But this is too deep a subject for us to sojourn longer.

We must return to our physicist and his description of experience. From the results of his experiments he seeks to frame laws which are brief, symbolic expressions describing certain apparent routines of experience. To call laws like those of Boyle, Ohm, Hooke, etc., to mention but a few of those familiar to every student of elementary physics, mere shorthand descriptions of actual laboratory operations is, however, to do injustice to their true significance. Rather the real value of a law is that it represents confidence in the possible repetition of a certain set of operations. The physicist, for example, after numerous experiments writes the equation $PV = K$, where P is the symbol for an operation which he calls measuring the pressure of a gas (and by which operation a number may be attached to P), V is the symbol for a corresponding operation called measuring the volume of the gas, and K is a constant as long as the temperature is constant. There is very little meaning or value in this expression if it is a description of merely one operation conducted at one particular place at one particular time. Its significance consists in the fact that it describes more or less faithfully a multitude of similar operations, irrespective of time or place. It contains within itself the power of prediction of the future, for it tells us, if at any future time we carry out a certain prescribed set of operations, just what we may expect to happen. It expresses our trust in a certain consistency of nature.

Now it is important to realize that this confidence in the consistency of nature is never justified in actual fact. No experiment ever gives precisely the result predicted by the law or laws which purport to describe it, and at times the discrepancy is very considerable. This, however, does not discourage the physicist, who is by nature an optimist. We must remember that though his business is to describe the world of experience, he does it by constructing a world all his own. This is what we may call the physical world. It should be called the physicist's world. It is the world where the physicist's laws never go wrong and never fail in their prognostications. I suppose we may say that it is his idea of heaven.

To say that the physical world is a world of symbolic laws is not enough. It is a world of theories, those conceptual generalizations from which all the laws descriptive of a certain group of phenomena may be deduced by purely mathematical means. Thus we have the theory of mechanics, one of the grandest generalizations ever created by the mind of man, and the concomitant mechanical theories of light, sound and heat. In

the building of each theory the physicist begins with certain concepts suggested by experience and defined in terms of actual or conceived operations through the use of naïve psychological notions. Such are, for example, the concepts of velocity, acceleration, mass and force in mechanics. These concepts are all expressed symbolically and certain mathematical relations are assumed to hold among them. In classical physics these are usually in the form of differential equations and constitute the fundamental hypotheses of the theory. From these hypotheses and the basic concepts deductions may be drawn by purely mathematical means. These deductions are themselves mathematical relations among the symbols. If they agree with the physical laws descriptive of phenomena in some field, the physicist says that he has a physical theory of these phenomena. Naturally the aim always is to make the theory subsume as large a group of phenomena as possible, and our satisfaction with a theory varies in accordance with its domain of validity. This, however, is not all. We want a theory to be able to predict new laws which will be verified by further experimental investigation. Close examination shows, indeed, that precisely this ability to predict is the real criterion for the success of every physical theory. When Maxwell, for example, predicted the laws of electromagnetic wave propagation from the electromagnetic theory he had built on the work of Faraday, he secured for the theory a much more wholehearted acceptance than would have been possible on the basis of the success with which the theory described phenomena already known.

We are now ready to see where causality fits into this picture. We have already noted that the physical world is a world of concepts, laws and theories, and in that world the physicist has complete control. What meaning does causality have for him? It must be confessed at once that the popular notion of cause and effect has little significance in his eyes. This notion expresses the tendency to separate every physical phenomenon into two parts, of which the first is said to be the cause of the second and the second the effect of the first. Consider as a simple illustration the extension of a wire by a weight, described symbolically by Hooke's law. The weight or at any rate the act of attaching it to the wire has been popularly called the cause of the extension, while the extension then figures as the effect of the weight, the idea being that with the force or weight in operation the extension takes place, while without it the extension does not take place. There may be a certain advantage in this popular version, and certainly it is an instinctive stand taken in every-day life. However, it has little value in the physical world. In the example cited, the physical law states a relation among symbols which represent well-defined laboratory operations, and there is no notion of precedence or antecedence involved in them. If this is the case, just what does causality signify? It means assigning universal and everlasting validity to every physical law. This implies in turn the possibility of the exact prediction of the future state of any physical system as soon as we know its state at any instant. The classical illustration of causality is drawn from mechanics. There are certain laws which purport to describe the motion of a planet about the sun. These are such that if we know the position and velocity of the planet at any instant we can calculate its position and velocity at any subsequent instant or indeed at any instant in the past. In other words, we may look upon the whole future and past of the mechanical system in question as strictly determined from its state at a given instant. In this sense causality is equivalent to determinism. The success that celestial mechanics has encountered in predicting actually ob-

served celestial phenomena like eclipses has of course gone far to emphasize the power of the causality principle as it is employed in classical mechanics. Nevertheless, it must again be borne in mind that, though strict determinism holds in the mechanics of the physical world, there is still no complete assurance that such will be found to be the case in the world of experience. The physical theory may make a prediction, but all we can say is that there is more or less probability of the prediction being verified. In many cases, such as that of the prediction of celestial phenomena, numerous trials have made us feel that the probability of verification is overwhelming, but even here we never expect to get exactly the result theoretically predicted. Even eclipses are apt to be a few seconds off. What conclusion shall we draw? Simply this—that though causality in the sense of exact determinism is a basic principle of the physical world, it does not hold in the world of experience. Does this mean that we live in a world of blind chance? We find it hard to believe that, and so we dilute the definition of causality somewhat by the admixture of a little probability. Most practical people do not object to this, and it certainly bolsters up our confidence in the utility of science. To be sure, there are some scientists who prefer to go the whole way and, because complete causality is impossible, become outright indeterminists with the thesis that all physical laws in their application to the world of experience have only statistical validity, that is, they work on the average; deviations and fluctuations must, however, be expected.

Now I do not wish to give the impression that the principle of causality has been universally employed, even in the construction of the physical world. Consider, for example, the kinetic theory of gases, according to which a gas is assumed to consist of a large number of small particles called molecules moving in straight lines in every direction with varying velocities and colliding frequently with the walls of the confining vessel and to some extent with each other. It is further postulated, at least in the simplest presentations of the theory, that each molecule is a rigid sphere and that its motions are to be described by the ordinary laws of collisions in classical mechanics (*i.e.*, conservation of momentum, etc.). This is of course a construction in the physical world and in particular one based fundamentally on classical mechanics. From this point of view the problem of the description of the large scale properties of a gas would reduce to the ability to calculate the position and velocity of every molecule at some definite instant of time. The number of molecules, however, is so great that this is a hopeless task. What do we do in such a quandary? We invariably fall back on statistical considerations. We cease altogether to fix attention on the individual members of the aggregate and concentrate on the average. This involves a theoretical departure from strict causality that we make cheerfully for the sake of convenience; and, of course, it is well known that the statistical theory of gases and more recently of liquids and solids as well has proved of enormous utility. I cite this illustration in order to stress the fact that the physicist does not always feel himself bound to use causal laws in the construction of the physical world. It is worth while to emphasize that, even in the development of classical physics, probability considerations have been used repeatedly, and no one has raised any hue or cry about it. The question then arises: What is the meaning of the present flare-up of anxiety?

The reason is to be found in the new quantum mechanics theory of atomic structure and in particular in the now famous principle of uncertainty or indeterminism of Heisenberg. This prin-

ciple is interesting because it purports to fix limits to the exactness with which measurements may be carried out even ideally. The now classic example is that of the electron. Suppose we wish to measure its position with great precision. It is then asserted that we must sacrifice precision in measuring its velocity; we must remain content merely with the probable value of the latter, or with the probability that the electron shall have a velocity lying in some assigned interval. More precisely still, if we denote by x and v the position coordinate and velocity of the particle, respectively, by Δx the limit of accuracy to which x can be measured (*i.e.*, the possible error in fixing x) and by Δv the corresponding limit for velocity, the principle may be expressed symbolically in the form

$$\Delta x \cdot \Delta v \geqq h/m$$

where h is the so-called Planck constant of action, of magnitude 6.55×10^{-27} erg sec, and m is the mass of the particle. According to the principle the product $\Delta x \cdot \Delta v$ is at least as great as h/m, though it is to be observed that the actual magnitude is not stated, the implication being that the order of magnitude of the product is that of h/m. It is clear that for particles of ordinary mass, the uncertainty predicted by the principle is negligible. However, this is by no means the case for a particle like an electron, whose mass in grams is numerically comparable with h. In this case, if Δv is very small, Δx may be relatively enormous, indicating complete inability to localize the electron if the velocity measurement is to be precise, and *vice versa*. The net result of the principle is thus frankly acausal or indeterministic. For, if we can not fix both position and velocity of an electron at any instant, we certainly can not fix its state at any subsequent time. We have lost our power of prediction with respect to it.

I should like to point out that in the form in which this principle is stated here, it is a deduction from rather specialized assumptions in quantum mechanics, rather than a definite result of the general postulates of that theory. It is indeed true that from the latter may be derived a theorem which, when translated into language involving our usual notions of space and time, is most naturally interpreted in the above fashion. However, it is only fair to add that this interpretation is one which assigns a meaning to such a thing as the measurement of an electron. It is perfectly possible to take the stand that such a measurement is really meaningless. This of course would entail the result that our physical world picture of such an entity as an electron as existing in space and time has broken down. Does this mean that the causality principle has gone into the discard? Not at all! It is true that if we wish, on the theory of quantum mechanics, to continue to think of electrons which can be localized in space and time we must sacrifice determinism. However, the theory of quantum mechanics does not force us to think of electrons in this way. It provides a perfectly satisfactory way of looking on the problems of atomic structure without invoking our usual space-time picture, and this way is certainly purely deterministic or causal in the usual physical sense. It is only when we try to translate the results of this theory into our usual space-time language that the failure of causality becomes evident. It is clear that in using our ordinary space-time concepts too closely in building the physical world we have been hampering ourselves unduly. Quantum mechanics shows the way to emancipation. It is a difficult way mathematically and there are probably not many except theoretical physicists who will care to try to follow it. This, however, is not important. What is important is that there is no

real breakdown of the principle of causality involved in quantum mechanics. Precisely as in classical mechanics, the difficulty occurs when we try to make the transition from the physical world picture of quantum mechanics to the world of experience.

There has been considerable speculation concerning our inability to construct a physical theory of atomic phenomena, using our classical notions of space and time, without running into indeterminism. Much has been made, for example, of the fact that all physical measurement is based on the possibility of observing a phenomenon without disturbing it. In order to measure anything we must go through certain operations. These imply the activity of an observer, whether he is on the spot in person or not. This is pretty obvious in the case of most laboratory operations, but it is well to emphasize the fact that even the act of looking through a telescope at a star in order to observe its position really disturbs the star. Of course in this and many other cases the disturbance is so monstrously small that we think little about it. On the other hand, it is conceivable that experiments in atomic physics are much more seriously affected by such disturbances. Thus to quote a commonly used example, if one wishes to locate an electron one must "see" it, and in order to see it, one must illuminate it. But the very act of illuminating it disturbs the electron so much that it is in an altogether different state after illumination than before, and examination indicates that the shorter the wave-length of the light (*i.e.*, the more sharply defined the electron), the more disturbance will the electron suffer. Indeed it is possible to give a kind of deduction of the uncertainty principle from an analysis of an experiment of this kind. It is possible to take the attitude that if there were no observer at all the electron would have its behavior completely determined. The lack of determinism on this view arises solely from the unfortunate presence of the observer. There are at least two possible solutions. In the first place one may absorb the observer (*i.e.*, the subject) and the thing observed (*i.e.*, the object) into one single system in which strict causality will reign, though of what earthly use it will be it is hard to see on the basis of our present view of the descriptive nature of physical science. On the other hand, it is possible to take the stand that man and his instruments are too closely a part of nature to be sufficiently objective in the description of experience, but that it is possible to imagine an ideal mind capable of observing and describing with no disturbance and with complete objectivity all that ever happens in the universe. This last idea has been suggested by Max Planck. It is further of interest to note that the subject-object dualism just touched on has been stressed in very interesting fashion by Niels Bohr.

How shall be conclude our brief survey of the problem of causality in the physical world? I think we may summarize by saying that there is such a thing as the principle of causality in physics and that it has played an important rôle in the building of the physical world. In this world and in this alone does strict causality in the physical sense reign. As soon as we try to make the transition from the physical world to that of our actual sense-perceptions, causality must be associated with the probability concept. However, there is nothing to worry about in this. The task of the physical scientist is to describe events and he is entitled in framing his description to use the most powerful methods which his mind can imagine. If adherence to strict causality entails too great complexity he will fall back on probability, as is evident from the wide-spread and increasing

development of statistical theories. This makes it sound foolish to talk about the breakdown of causality in the more recent theories of the atom. The use of the causal principle is just as possible as it ever was, and if some physicists want to give it up it is only because they prefer to retain the classical space-time concepts as the scaffolding for their theories instead of the more ethereal abstractions of quantum mechanics. The choice is theirs to make; no one can quarrel with them, for in the last analysis the question is one of taste and can never be settled on purely logical grounds. I hope I have succeeded in conveying the impression that the question of causality *versus* acausality, determinism *versus* indeterminism, in the physical world, is after all not so terribly important. We may rest assured that, armed with both powerful methods of description, the physical scientist will go forth to attack with renewed vigor the fortress wherein lie hidden nature's mysteries.

THE ATTACK ON THE ATOM

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WHAT is the structure of atoms? What is the nature and the arrangement of the parts of which atoms are built? What is the character of the forces that hold these parts together? How much energy do atoms possess and where is this energy located? These are important problems, to the solution of which many physicists are at the present time directing all their energies. The opening skirmishes of this battle for knowledge have already taken place. The rings of outlying fortifications have fallen and we have here but to consolidate the ground gained. The heavy artillery is even now engaged in the final assault upon the nucleus, the central citadel of the atom wherein lie hidden the main treasures we seek. A continuous shower of projectiles has already made some minor breaches in the walls. New guns are hurriedly being brought into action and new weapons ever more powerful are in process of construction. No man can tell how soon the end will come, but be it ten years or a hundred the battle will go on with undiminished zeal until victory is won. Science does not count cost nor ask what price victory. All this activity has not escaped public notice. Every layman is informed through the daily press of what is going on. What is said here must necessarily be in the nature of a survey of the situation.

It may not be amiss to point out at the outset that when we enter the domain of the atom we are on ground where the ordinary laws and concepts of physics, which we use with such confidence in connection with gross matter, have not been tested and may not be directly applicable. It must also be admitted that perhaps we have been too confident as to our understanding of the real significance of the fundamental concepts in terms of which we describe the physical world. Our knowledge of these concepts is in reality limited in character.

Let us consider for a moment the term we call the mass of a body and see in what new light we must look upon this concept when dealing with atoms. We have learned that the electric field about a charged body offers an inertial resistance to accelerated motion and thus has the fundamental attribute which we ascribe to mass. A charged body therefore has more mass than an uncharged one. The smaller the space into which a given charge is concentrated the larger the mass associated with it. By supposing a charged atom sufficiently reduced in size its whole mass may be ascribed to its charge. This supposition has indeed been made in a theory which considers all matter to consist merely of an assemblage of electrical charges. When two oppositely charged bodies are brought near to each other the contrary fields associated with those charges become in part annulled, owing to overlapping, and accordingly a portion of the mass disappears. The sum of the masses of two oppositely charged bodies is therefore greater when they are far apart than it is when they are close together. The effect is really only appreciable at very small distances, but, as we shall see, it plays an important part in atomic structure theory, in what is known as the packing effect.

Furthermore, it has been found that the mass of a charged body increases

when its velocity is augmented. The increase in mass is inappreciable for ordinary velocities, but it becomes great at velocities approaching that of light. Thus the mass of a body is seen to depend on its kinetic energy, and Einstein, by an extension of this idea, made the whole mass of a body depend solely upon its total energy content, be this energy kinetic or potential. Accordingly, when a body loses energy it loses mass. When it gains energy it gains mass. A body radiating energy does so at the expense of its own substance. In this manner, four million tons of the sun's mass are supposed to be transformed every second into radiant heat. Mass and energy are but two different aspects of the same entity. In atomic relations we may speak of the conservation of mass and energy only when the two are taken together and not when considered separately.

Another important generalization made by Einstein must be mentioned. Planck had found it necessary to assume that radiation is not transferred continuously, but that it is given off in definite units called quanta. To account for certain experimental results Einstein considers these quanta of radiant energy localized in small volumes which do not spread during propagation through space. It is thus possible for a quantum of light to be emitted by the atom of one body and be delivered intact to a single atom of another body at a great distance. The electromagnetic wave description of radiant energy transfer can only be considered valid in a statistical sense based on probability considerations.

As far back as 1815, Prout, noting that the atomic weights of many elements are close to being whole numbers, enunciated a hypothesis that the atoms of all the chemical elements are composed of varying numbers of hydrogen atoms linked together. There was serious objection to the hypothesis because of the many exceptions to the whole number rule. The discovery that the atoms of many elements are not all alike and new measurements of their weights have for the most part removed this difficulty. The weights of all individual atoms actually approximate whole numbers when compared to oxygen taken as 16. Nevertheless, the small observed differences from whole numbers are too large to be attributable to errors of experiment. These differences have been accounted for, in a manner already explained, by supposing them due to loss of mass resulting from close packing of the elementary charges that make up the atoms.

But have we no evidence of the structure of atoms that is more positive in character? These objects are naturally far too small for direct observation. How then can we learn anything about them by experiment? We do this by bombarding the atoms with high speed particles or by quanta of radiant energy and look for effects of the collisions both on the bombarding particle and on the atoms bombarded. Observations of electrical discharges through the residual gases in highly exhausted tubes showed the presence there of negatively charged particles having a mass only a little larger than one two-thousandth that of a hydrogen atom. These particles, now called electrons, were torn from atoms by violent actions within the electrical discharge and they are the first chips obtained from atoms. They are found to be building stones, common to the atoms of all the elements.

Since an electron is charged negatively the remainder of every atom must have a resultant positive charge. What can we say regarding the spatial distributions of the two electricities in atoms? Rutherford bombarded metal foils with positively charged particles and from the angles at which these particles were scattered he was led to conclude that the

positive portion of the atom is concentrated into a very small region, only a few millionths of a millionth of a centimeter in diameter. This is roughly about one ten-thousandth of the diameter of the whole atom. Here then started the prevailing theory of the nuclear atom, according to which the atom is a very open structure resembling our solar system. There is a central positively charged nucleus which contains nearly the whole mass of the atom and is its vital portion upon whose integrity the identity of the atom depends. Surrounding the nucleus there is a swarm of electrons ranging in number, in regular sequence for the different chemical elements, from 1 to 92 and arranged at various distances in the so-called energy states or levels. These negative electrons just offset the positive charge on the nucleus so that, at considerable distances, the atom behaves like an electrically neutral body. These outward defenses of the atom have been subjected to intensive study by noting the effects of bombardment with electrons of various speeds and by measuring the frequencies associated with the light quanta that they emit. We already know the energy relations between the different levels and the number of electrons belonging to each level. The energy required to remove one of the outermost electrons from an atom may be stated as equal to that acquired by an electron in falling through a potential difference of but 10 or 20 volts, whereas for the removal of one of the innermost electrons from an atom of high atomic weight an electron must acquire energy by falling through more than 100,000 volts. To account for some of the effects observed it has been necessary to assume that, in some cases at least, the electrons and the nucleus as well are spinning like tops.

As to the exact locations and velocities of the electrons in the different levels, we can but speculate, since these do not permit of direct observation. Bohr gave us an atom model with electrons revolving about the nucleus. This met with success in explaining some of the radiations from hydrogen atoms. Many physicists still like to picture atoms in this way. Chemists, however, prefer to think of a static system of electrons, since the outermost of these electrons serve as bonds for holding atoms together in the formation of molecules.

We come finally to the nucleus, the innermost portion of the atom. Protected as it is by its outer rings of fortifications and by its own formidable wall, how are we to learn anything about what is within? Paradoxical as it may seem we have thus far learned most about the nucleus by doing but little more than use our eyes. Close observation from the outside of some of the families of the heavy elements, like the uraniums and the thoriums and actiniums, brings to light the fact that the inhabitants of these nuclei lead lives full of stress and discord. Here out of the window of one of them we see hurled a large missile with a velocity of more than 10,000 miles a second. Out of another window comes a smaller object having more than ten times this speed. And now here comes, dare we say, an etherial entity so energetic that the likes of it have never been seen before. We gather up these fragments that have been cast into the street. We study them and weigh them. We recognize in the alpha particle a helium nucleus. The beta rays turn out to be electrons and the gamma rays are but light quanta of very high frequency.

Considerations based on wave mechanics lead us to look upon the walls of nuclei as high potential barriers. A charged particle within these walls normally does not have sufficient energy to surmount them, but there is a small probability that now and then such a

particle may pass right through the wall, by means of a window if you like, without loss of energy. Careful measurements made of the speeds of alpha particles, the heavier of the pieces ejected, show that the speeds of the particles coming from any one element are as a rule identical. In some cases, however, groups of particles with different velocities are found, indicating that these came from different potential levels in the nucleus. This view that there are definite potential levels, within the nucleus as well as on the outside of it, is strengthened by the observation that in these cases gamma rays are found with energies corresponding to the differences between the kinetic energies of the alpha particles coming from the same element. The conclusion drawn is that when an alpha particle falls from one potential level to another within the nucleus the potential energy lost appears in the form of a radiation quantum having this particular amount of energy. Conversely, it has been found possible, by bombarding some nuclei with energetic γ rays from another substance, to raise some of the alpha particles within them to higher potential levels, as is evidenced by the increased speeds they possess when they get out of an atom under these circumstances.

The recital thus far has had to do with the nuclei of radioactive substances and we have learned that helium nuclei and electrons are contained in these nuclei and that the helium nuclei are at times found in different energy levels differing by definite quanta.

A new stage in the study of the nucleus was reached when Rutherford bombarded the nuclei of ordinary, nonradioactive elements with alpha particles and succeeded in ejecting from some of them high speed hydrogen nuclei or protons, as they are now called. To this third component of atomic nuclei there has recently been added a fourth and lastly a fifth. The fourth component, in order of discovery, was obtained by bombarding elements like beryllium and boron with alpha particles. This new entity is quite unlike the other three in that it carries no resultant charge. It is accordingly called a neutron. The mass obtained for it corresponds very closely to that of a proton. The properties of this new particle are now being studied intensively in many laboratories throughout the world, and it is hoped that its real nature may soon be disclosed. Since the mass of the neutron is approximately that of a proton, two theories proposed for the structure of the neutron both consider it to be a close union of a proton and an electron. According to one theory the proton and electron are held firmly together side by side. According to the other theory the proton is located at the center of the electron, being completely surrounded by the latter. A third more revolutionary theory considers the neutron to be a new elementary particle, in no way related to a proton. Experiments now being carried out on collisions of neutrons with protons appear to favor the last theory. Should this conclusion prove correct we may possibly be faced by the problem of a new kind of force not now recognized. The neutron, because of its uncharged condition, has the power to pass readily through large thicknesses of matter. Its course is only affected by a direct collision with the nucleus of some atom. During such an impact the neutron may be captured by this nucleus, become incorporated in it and either form one atom of a heavier element or after subdivision give birth to two different atoms.

The fifth and last particle to be discovered is the positron. This particle has the same mass as an electron but it carries a positive charge instead of a negative one. The properties of the two

may well be almost identical. Some positrons have been obtained by subjecting atoms to gamma radiation from radium. Others, some with energies as high as 800,000,000 electron volts, either came to us directly from outer space or are ejected from atoms by the action of the so-called cosmic rays.

The experiments on nuclear disruption naturally present difficulties. The nucleus is not only a very small object to shoot at, but we do not even know where it is. We are somewhat in the position of a hunter who fires into the sky on a dark night and hopes to bring down a goose. The only hope of success lies in shooting continuously for a long time with many bullets and trusting that one of them may find its mark.

Until recently the most energetic projectiles at our command have been alpha particles. Their energy is represented by several million electron volts. By their use we have succeeded in knocking various particles out of the nuclei of some of the atoms. Where we have failed, it is possible that the nuclei may possess these same or have other particles so firmly lodged that our projectiles have not been powerful enough to break them away. To overcome this difficulty artificial guns have already been constructed and others are being perfected capable of giving us projectiles even more energetic than alpha particles and many, many times more numerous. No such stupendous physical apparatus has ever been assembled previously. At one university immense spheres 15 feet in diameter, supported by pillars 24 feet high, form a part of the equipment. In other laboratories gigantic magnets of great weight have been built. At other places powerful but less spectacular apparatus is being constructed and pressed into service. No attack so formidable as this has ever been directed against a physical problem.

The purpose of all these great engines is to give electrified particles tremendous velocities and then to hurl them in great number against the nuclei of various elements with the hope of shattering these nuclei more completely than has as yet been found possible. It may well be urged that our method for investigating the machinery of a nucleus is a very crude one; that if we wished to learn how a delicate watch works we would not put it on an anvil and hit it with a hammer. However, we have no alternative. No one has yet improved on the ballistic method of getting the meat out of a hard nut.

With the new equipment already in use a number of nuclei have been shattered, some by use of protons having energies of but a few hundred thousand electron volts. As yet no new types of particles have been obtained, although our knowledge regarding several nuclei has been extended. However, the battle has scarcely begun.

It must be remembered that owing to their scarcity it is no easy matter to detect and recognize fragments of nuclei even after they have been dislodged. Unless a fragment flies off with so high a velocity that we may see the havoc it creates among molecules along its path, we are lost. As larger and larger pieces are dislodged the difficulty of giving them sufficient velocities to enable us to measure their masses becomes more and more formidable.

Composite portions of a nucleus which fly off as one piece are naturally held together by stronger bonds than the bonds which hold these parts to the other constituents of the nucleus. A knowledge of what parts cling together most strongly and of the energies necessary to dislodge them gives us some basis for computing the nature of the forces active within the nucleus. The helium nucleus or alpha particle is a constituent of many nuclei because it is

a highly stable unit. The more elementary particles composing it are held together so closely that its energy content is relatively small, as is indicated by its mass defect, or as this quantity was previously called its packing effect, being unusually high. There is an expectation that particles of half the mass of an alpha particle may be separated out of the nuclei of some of the elements. Such particles would correspond to the nuclei of the heavier isotope of hydrogen, recently discovered. Rutherford has expressed the opinion that we may find a neutral particle of twice the mass of the neutron. An important question to settle is why atoms whose weights are certain multiples of the proton, for example, 3, 5, 8 and so on, are never found in nature. Why are these combinations so unstable?

When we shall have assembled all the pieces we shall be in a better position than now for beginning the work of fitting them together so that we may see the pictures that the different atoms present. Even after the parts of the nuclei are all known and in place, we may still be confronted with unknown aspects of the forces that hold these parts together.

The known problems to be solved are still many, and their solution is almost certain to disclose other and more difficult problems. We do not shirk the task. We are embarked upon a journey that knows no end. We are climbing a mountain that has no top. We do not understand the urge that drives us on. Sufficient for us are the new glimpses of nature's panorama that each forward step reveals.

THE NEW BURDEN ON BEHAVIOR

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SOME years ago when the suggestion was made at a meeting of the British Association for the Advancement of Science that science should take a ten-year holiday, it was received with a smile of indulgence. Since that time, however, there have been recurring expressions of the view that scientific effort should now be turned in other directions than the furthering of our knowledge of our physical environment and our control over it. Professor Millikan, in his chapter on the "Alleged Sins of Science," has attempted an answer to these demands, an answer not wholly convincing. Mr. Julian Huxley, in the course of a lecture at Stanford University, said that one of the next duties of science is to study social life, into the general field of which it has not far advanced.

In the present article, I wish to call attention to certain remarkable social changes which seem to point to the absolute necessity of turning a larger part of the tremendous intellectual power exhibited in scientific thought and research into social and ethical fields, if our western civilization is not continuously to decline. It should be remembered that the trite phrase "downfall of our civilization" does not mean any romantic cataclysm of war or revolution, but the steady decline of our standard of living; at the worst it means dirt, disease and misery. It is not pleasant to recall that in the study of ancient cultures we have to dig down through successive layers of dirt.

Of the social changes to which I have just referred, probably the most significant are these three—our superabundant food supply, our increasing leisure and our shifting standards of behavior. When the "prosperity" for which we are all praying comes, we shall have to face these problems, and we can not do this without scientific knowledge of their interrelations. We shall have to ask how these changes are going to affect the real prosperity of our children, their children and grandchildren. Our interests are almost wholly with economic questions, with the return of good times, with work for all and good wages, with the hum of mill and factory. We have little concern with the to-morrow of our children.

The forgotten man is evidently the man of the to-morrow. Though we may not be interested in any astronomical future of our race, nor in theories of a decadent civilization, we are surely interested in the to-morrow of our children; and sometimes it may occur to us to wonder how their future will be affected by our behavior in the prosperous times which we hope will soon return.

It is just this matter of behavior which is the neglected factor in all our plans for national prosperity; for it may turn out that in human behavior we shall find not only the key to the welfare of succeeding generations, but also the cause of most of our own troubles. Within the period since the world war—one might almost say within the last five years—certain strange things have happened which disturb all our old social views, and may perhaps force us to revise all the old theories of progress.

But let us go back of this for a moment. It has generally been accepted that there are four conditions of human happiness and social progress, and four only. These are: (1) An abundant food supply—abundant and continuous; (2) a favorable climate, including freedom

from destructive floods, storms and earthquakes; (3) a reasonably stable and beneficent government, insuring individual liberty and opportunity; (4) freedom from disturbing wars and foreign invasion. Give us jobs, good wages and economic justice; give us good government and opportunity; give us freedom from war and oppression, and we shall be happy—and well-behaved.

If all this be true and if these be the four conditions of prosperity, then the outlook for the future in America is most alluring, since it appears that all these conditions are to be abundantly fulfilled.

Of the four conditions, that of food supply has always been considered primary. When it fails, primitive people move to other fields or perish from starvation. The English economists predicted disaster for mankind because of the basic law of the rapid increase of population and the slow increase in the food supply. But now it appears that all this is changed. Malthus got his terms mixed. It is the food supply that increases by leaps and bounds, while populations increase slowly or not at all. Science has learned how to increase the fertility of the soil and to decrease the fertility of people. With amazement or even with alarm, we have witnessed in the last few years the accumulating supply of superabundant food. Science has discovered new varieties of wheat suitable for more northern climates. It has invented machines, simplifying the preparation of the soil and the harvesting of the grain. It has discovered new sources of fertilizers for impoverished soils and new methods of irrigation for rich desert lands. It has discovered new means for combating insect pests which threaten agricultural products. Famine, that ancient and persistent enemy of progress, is yielding to the advances of scientific study and experimentation.

But while food was the all-important thing among earlier people, it is now just one of many things which we consider necessary for our happiness and well-being. We want good clothes, good houses, bathrooms, public and private sanitation, public and private electric lights, pure running water, furnace heat, motor cars, radios, medicines, cosmetics, cigarettes, newspapers, books, magazines and a host of other things. Perhaps these will fail in the to-morrow of our children and their children. But no, it appears that there is to be no shortage of any of these things, whether of manufactured articles, raw material or natural products. Already we have factories and skilled labor for supplying not only our own people but many others with manufactured goods of every kind. And an army of technicians awaits our call for still other articles of production and for means of supplying them.

The second condition of human happiness, namely, favorable climate, need cause us no concern. Nineteenth century fears of a gradually freezing planet with visions of the last forlorn inhabitant shivering over a pile of dying embers have vanished with our new astronomical knowledge, and we are now assured that Mother Earth will offer a genial climate, well fitted for human happiness, for at least a million years. "Fair and mild" is the weather forecast for the next few hundred thousand years. Earthquakes will occur more rarely, and storms will gradually become less destructive.

But what about our third condition of welfare, that of a reasonably stable and beneficent government, guaranteeing protection, freedom and opportunity to all the people? Here again the future is bright with promise. All the tendencies of our modern era are steadily in the direction of greater political stability and the increased beneficence of governments. National boundaries become more and more sacred, and international relations are determined more and more by reason and justice, and less by mili-

tary force and oppression. Even when a far distant oriental nation ventures with its armies across the boundary line of another people, the protests of all civilized nations as well as those of many of its own people are heard around the world. Relations also with colonial possessions are more and more governed by motives of benevolent service, and less by those of commercial and industrial exploitation.

Neither can we doubt the beneficence of the political state of the future. Revolutions will occur, as they are occurring now, and in times of economic depression they may multiply; but they tend more and more to be bloodless, and the daily routine of the people goes on much as before. A labor government comes into power in England, and no great change takes place in the relations of the people to the government. In Fascist Italy, in republican France, in imperial Britain, in democratic America, there continue to be public schools, public libraries, public care for the helpless, the sick, the insane and the feeble-minded, state inspection of foods, pure food and drug laws, sanitary regulations, the education and protection of children, increasing rights and privileges of women, safeguarding of the rights and wages of workers, efficient police protection, convenient postal and telegraph systems, improved public highways and airways, various forms of social insurance, state regulation of systems of transportation, and so on through the long list. These are merely illustrations of a public beneficence with which we have become so familiar that we take it all for granted. No government would long endure that does not provide such things. Governments are becoming more and more efficient, and government is becoming more and more an exact science.

In the America of to-morrow, as in other states of the western world, we can not doubt that these and many other forms of public beneficence will be present. Experiments in the form of government there will no doubt be. Capitalism, collectivism, socialism, conceivably even Fascism or communism may be tried; but the state will go on, and there will continue to be colleges, universities, free public parks, art galleries and museums. We shall still be able to send our letters across the continent or to foreign countries for a few pennies. There will still be telephonic communication around the world, and we can still ride comfortably and safely by water, rail or air. For the government of the future, then, we may confidently predict both stability and beneficence, and an increasing degree of each.

Now what of the fourth condition of human happiness and social welfare, namely, freedom from war and from foreign oppression? Here also we may look to the future with hope and confidence, not only in America, where confidence is the greatest, but throughout the world. An increasing number of men and women of every land are becoming conscious of the hopeless futility of war. They are beginning to understand its frightful cost, financial, economic, political, social, biological and moral, and its monstrous waste. It is this wide-spread growing consciousness of the iniquity and uselessness of war which from generation to generation will lessen its frequency. Furthermore, a wholly new and powerful motive toward the maintenance of peace has arisen. The interests of the western world have become primarily commercial, financial, industrial and economic, and secondarily political; and all these new interests have taken on intricate international relations, into which war enters as a fatal disturbing factor. Finally, war itself has been made somewhat ridiculous, owing to the leading rôle which the moving picture industry and the feverish news service industry now take in the actual drama of war. When battles begin to be filmed, they will soon cease to

be fought. Wars no doubt there will still be, but they will steadily become less frequent and less important. The destiny of nations in the future will be determined not by war but by the integrity, sturdiness and discipline of the people.

It appears, then, that the four traditional conditions of prosperity will be abundantly fulfilled in the to-morrow of our children. There will be a more than adequate food supply, even for increasing populations. There will be favoring climate, stable and generous governments and a growing freedom from devastating wars.

And yet few writers in any field of physical or social science, literature, art, or philosophy venture to predict for the future any degree of social welfare or human happiness commensurate with our wealth and our opportunities, while predictions of a complete collapse of our western civilization are many and portending.

How shall we explain this strange situation? The explanation is not far to seek. It is because in our modern complex society there is another condition of prosperity and happiness than plentiful food, manufactured goods, friendly climate, good government and peace among nations, and this other condition is human behavior; and, owing to the complex character of our present civilization, and the new and crowded relations under which we live, this new condition of prosperity has become supreme and overshadowing. The old cry of the people, "Give us jobs, give us peace, and give us the right kind of government, and we shall be prosperous and happy," must in the future be supplemented by a conditional clause—provided we behave like human beings.

The old idea that crime will disappear with the advent of the full dinner pail and that with the coming of economic prosperity, the people will devote themselves with industry and sobriety to honest toil, spending their leisure hours in creative art and in innocent amusements, has been long since discredited. In those overflowing years preceding the great depression, we had jobs, we had money, we had peace with other nations, and we had a stable and beneficent government, but our jails and prisons were crowded and the era of gangsters and organized crime began in our cities.

That the sorrows and sufferings which in earlier communities followed from famine and flood, war and invasion, and the oppression of ruling classes and tyrannical governments, are due in our modern society to human misbehavior and to human folly and incompetence is apparent as soon as we begin to reflect upon it. Our thought naturally turns first to the depression, and the catalogue of its causes is gradually taking form. But whether these causes are to be found in our imperfect economic organization, our fanatical neglect of any rational adjustment between production, distribution and consumption, our wasteful competition, our unorganized individualism, our reckless and greedy speculation, our thoughtless enlargement of industrial and commercial enterprises, our popular extravagance and waste, our foolish misuse of instalment buying and selling, or finally in our artificial restriction upon international trade through unwise tariffs and the overturning of normal trade relations by the post-war system of reparations and war debts, it is evident that it all comes back to somebody's mismanagement, incompetence, folly or misbehavior.

Or, if we choose, however wrongly, to trace the whole trouble back to the war, the war itself was a gigantic misadventure, having its roots in foolish international rivalry and jealousy. We are coming now to regard the world war as a series of fatal blunders, of which the Treaty of Versailles was the crowning example, unless we except the failure of the United States to assume at that time

the generous leadership, political, economic and moral, which was within its grasp.

I have taken the economic depression as an illustration of the fact that in this modern era our many ills are due to our many errors. But any other illustration would have done as well. If, for instance, we try to discover the ultimate sources of the crime wave with its organized banditry, its bootlegging, racketeering and kidnapping, we come back always to some form of human greed, corruption or incompetence, or to some form of physical or mental defect. The story is the same, whether we trace our crime to delay in the administration of our criminal laws or to our dilatory courts, our weak juries, our corrupt officials, or our venal politicians.

In many cases, we find the source of crime in the behavior of fathers and mothers, leading to the birth of children with abnormal brain patterns or glandular deficiency. Possibly slenderizing fashions, high-heeled shoes, immoderate or indecent dancing, cigarettes and cocktails on the part of mothers may have something to do with bad behavior on the part of sons and daughters.

Possibly, indeed, we should go still further back in our search for the cause of crime and find some of it in human interference with Nature's selective method of breeding a hearty and healthy race. We tremble for the nation's future when we are told, for instance, that every second bed in our thousands of hospitals is occupied by a person having some form of nervous or mental defect.

Just now it is the fashion to place the blame for our crime wave upon our prohibitory laws. But in any case it would go back to the lawmakers or the lawbreakers. Somebody went wrong, whether we put the blame on unwise legislation or on wilful disobedience to law or on mass emotion and hysteria of a fickle people, soon tiring of their self-imposed temperance. If the law was a bad one, we did wrong in making it; if it was a good one, we did wrong in breaking it. The spectacle, at any rate, of a great nation quarreling over the percentage of alcohol which it can have in its drink, at a time when really serious and fateful economic and political problems are before it, is certainly not edifying. It is ludicrous and humiliating, and makes us appear like a nation of children.

The recent rapid increase of divorce, the threatened disintegration of the home, the emphasis of sex in present-day fiction and the moving pictures and the advent of "easy standards" among both young and old are all deeply significant social changes, placing a new burden upon behavior as it relates to the future health and happiness of our children and to the endurance of a strong and virile nation.

The front-page headlines of a metropolitan newspaper announce that a celebrated tennis queen lauds woman who breaks conventions, and an advertisement in one of our standard monthly magazines praises a new book as "an exquisite story of love transcending all conventions" and breaking through the barriers of false morality. This is "the new freedom for women."

The increasing cigarette habit may or may not be for the nation's hurt, but it indicates a serious social change; and when the publisher of a widely circulating magazine must decide whether he will or will not for a glittering sum accept a highly illumined and seductive advertisement of smokes for women, his decision is of great social import.

These instances I mention not to pass judgment upon conduct or customs, but as an illustration of the burden of social responsibility which rests upon editors, publishers, picture producers and writers of fiction. The social responsibility of the teachers in our schools has always been recognized; but the change has

been so sudden that we fail to comprehend to what extent the education of the young is now in the hands, not of our schools, but of the daily and monthly press, the news stand, the circulating library, the moving pictures and the radio.

In former times there was no such burden upon individual behavior and no such responsibility resting upon those holding positions of influence, since conduct was regulated by custom. Those social groups whose customs did not have a favorable balance of survival value perished or were reduced to slavery in the fierce struggle with other hostile groups or with the forces of nature. In modern times behavior has become reflective rather than customary, and great issues depend upon the reflection and decision of the individual. If behavior should become neither reflective nor "customary," but impulsive, organized society would be near its end.

Since then the happiness and prosperity of ourselves and our children depend not upon the mood of Nature, or our physical environment, but upon human behavior and our social environment, it becomes of supreme interest to inquire what equipment the man of the present has for bearing this new burden.

A candid answer to this question reveals a strange situation. It appears that, although every other science has been developed to a high degree, the science dealing with the relation between human behavior and human happiness is in its infancy. We have no exact scientific knowledge of good behavior comparable with our knowledge of the physical world possessed by our astronomers, physicists, physiologists and chemists. And in this connection let it be clearly understood that by good behavior we do not mean that which conforms to any ancient code of conduct or to any moral custom or tradition, but solely that kind of behavior which is necessary for human happiness and social health, both for the present and coming generations.

In the field of behavior our knowledge is fragmentary and chaotic, and our attitude toward such problems differs wholly from our fine confidence when we face the problems of science, even those of the most abstract and difficult kind, such as the theory of relativity or the nature of space; and we have no company of great minds and distinguished scientific men working upon the problem of behavior, and no great public interest to inspire the search and reward the solution. There is probably more public interest in dispelling our ignorance of the interior of the Antarctic continent than in solving the problems of human behavior as it relates to the health and happiness of our children; and our equipment for answering the geographic question is better than for solving the social one. And yet unless we can solve this social problem, our whole wonderful and really great civilization is in peril.

Nothing could be more fraught with danger than the confusion and bewilderment which exist in the minds of our people, both young and old, about such questions as the position of divorce in a healthy social group, the relation of the sexes both before and after marriage, the effects upon racial health of the constantly increasing use of alcohol and tobacco, the limitation of desires *versus* increase of production, the social advantage of saving *versus* spending, the relative value of self-expression *versus* self-control, the social responsibility of our writers of fiction and of publishers, editors and producers of pictures, the conservation of racial health and the practice of birth control. There is not only no code of behavior in respect to these various issues but there is no exact knowledge regarding them, and no fact-finding commission investigating them, and no plank concerning them in the platform of either of our great political parties.

Furthermore, as our civilization becomes complex and our communities crowded, a new burden is placed upon all the old virtues which experience has found to be necessary to communal living, such as respect for life and property, the sanctity of marriage and the home, justice, honesty, veracity, fair play, temperance, cleanliness and chastity. Civil law can attempt only a partial regulation of these and only in cases of serious violation. For the rest we depend upon ancient codes of conduct, tables of commandments, custom, public opinion and religious authority; and something very near to chaos exists today, not only in respect to the validity of these codes, but also in respect to the sanctions for them; and we are without scientific guidance in this matter. These ancient codes have come down to us by social inheritance and are unsifted and unverified. We demand to know whence they come and what their credentials are.

Divine authority has often been claimed for the traditional codes of behavior, possibly, we mistrust, by zealous though not quite truthful priests and prophets of religion. But we demand to know whether God has indeed ordained them; and, anyway, we wonder what kind of laws would be made by an all-wise legislator, legislating for a machine age like ours, with its congested cities, its complexities of industry, finance and international relations, its conflicts between labor and capital, its increasing longevity and decreasing fertility, its revolutionized position of women, its unhappy gap between the age of puberty and the age of marriage, its craving for sedatives such as alcohol and tobacco, its abundance of leisure, its new scale of values in an age of sports and recreations, and its new and bewildering Freudian psychology.

It is partly our prevailing skepticism and partly our feeling that the traditional laws of behavior are not adapted to our new age that has cast a shadow of doubt upon all the ancient *mores*. But the fatal result has been that in discarding the rules that were bad, we have rejected those that were good. There is danger, indeed, that we may reject those that are vital to all social living, those that have through all the centuries grown out of the hard experience of social groups.

And we have no Five Year Plan for establishing a national code of behavior which shall separate the true from the false in the old conventions; nor have we any such plan for adapting by scientific examination the ancient codes to modern conditions. We have fact-finding commissions to report on the economic and financial problems of the day, but no such commissions or advisory councils or committee of experts to determine which of the old rules of behavior were just taboos or silly conventions and which are vital conditions of social survival.

The solution of this whole fateful problem seems to lie in giving a new direction to both theoretical and applied science. Whether the spirit of the age will change in time to effect this new direction is a question which no one can now answer. Science has surrounded us with comforts and conveniences, increased our life span and changed our daily habits; it is now time to study our behavior in this new environment. We have plenty of gadgets of all kinds for dealing with the material world; but our equipment for successful communal living is out of date. We need a genius like Einstein to tell us not any more about space and gravity, but how to behave in this new and perplexing world —and why.

Our most pressing need to-day is a new set of ideal behavior patterns. Those that we have were adapted to sparsely inhabited agrarian communities. They are now as much out of date as a tallow candle for lighting our homes, or

a horse and buggy to carry us to the city. Science has given us electric lights and motor cars; now let it give us a new set of behavior patterns. If it is replied that the task we propose is beyond the power of all organized effort and beyond the wisdom of all our wisest men, it must be remembered that this is what has been said concerning most of the miraculous achievements of modern science.

In fact, we are turning more and more to the experts in all fields of endeavor, for instance, in the field of government. Even if our members of Congress should be chosen because of their intellectual power, they could not solve the complex problems of government to-day. We depend more and more on commissions of experts in the several fields. Ignorant audiences applaud satirical jibes at government by commissions and approve of proposals to abolish them and balance the budget; but we need more of such commissions—not fewer. We need men who know. We need them for economic planning; we need them still more for social planning. Plato explained all this to us more than two thousand years ago, but we have learned his lesson poorly.

Of course, there is that other age-old problem concerning the forces or sanctions which society can bring to bear upon individuals to ensure obedience to ideal codes of behavior, but it is perfectly obvious that the first step in this direction is the authoritative establishment of such codes, and the authority of science is the one thing which the modern man still respects. The forces of social control which have been effective during the history of mankind are custom, public opinion, religious authority and the authority of the state or its representative. But the commanding force of both custom and religion has become greatly lessened. We demand to know their credentials. And as for the authority of the state, our late experience with prohibition has revealed to us the difficulty in enforcing laws for which the people do not see the need. The people themselves demand to know the reason for the law.

In former times it was enough to know that God had said Thou shalt, or Thou shalt not. Again it was enough to know that the chief or king had issued a command. And again through all the ages it was enough to know that it was the custom of our fathers or of our neighbors. But times have changed. We want to be shown. And science is the only authority left to show us.

But if we are shown, will we obey? or have we become essentially a lawless people? If any one thinks that we are not a law-abiding people when we can see the purpose of a law, let him study our traffic regulations. Let him take his stand at some busy crossing of one of our great motor highways. Probably no officer is in sight, but hour after hour, day and night, the drivers, with machine-like regularity, bring their speeding cars to a stop before the red light and again move on with decorous precision at the flashing of the green; and they prate not of personal liberty or inquisitorial laws or the right to regulate their own cars according to their own views. They stop when the signals say "Stop." And the reason for this docile obedience is clear. We love to drive our cars, and even the dumbest of us can see that the traffic laws are necessary to that end. The penalties are swift and certain, and public opinion supports the regulations.

It is not alone in the case of traffic rules that we are a law-abiding, humble and decorous people. Similar discipline is seen in the conduct of our sports, of our large commercial houses, of our transportation service, and in many other fields. But in all these faithfully observed rules and regulations there is one clear and definite end, namely, that

we may carry on in the pursuits in which we are vitally concerned—in industry and commerce, in sports and recreation.

In the case of laws or social customs which relate not to our immediate interests but to the conservation of social or racial values, such as the health and happiness of our children and the integrity and stability of our nation, it is difficult to mobilize public opinion in enforcing laws or conserving customs. To take a single instance, it may well be and probably is true that the social and racial damage done by the use of alcohol is almost infinitely greater than any injury done to life or property resulting from the infraction of our traffic laws. But we do not know this to be true, although laboratory experiments and the experience of social workers seem to confirm it. The question must be passed upon by those who know, and by those in whose word the people have confidence. The solution of the wet and dry problem seems then to lie in the field of scientific inquiry and authority, and when science has spoken, its decisions must be made known through every educational channel, the school, the daily press, the radio, the movies and the news stand. Whether in a democracy like ours customs can be conserved and laws passed and enforced which relate to a future no more distant even than the maturity of our children is a question which only time can answer. My purpose in this paper has been not to discuss this subject but only to call attention to the new and terrific burden which modern society has put upon behavior, and to express the belief that this burden can be borne only when the enormous power of scientific thought has been turned in this direction.

THE USES AND LIMITATIONS OF THE STATISTICAL METHOD IN THE SOCIAL SCIENCES

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CONTRARY statements as to the scientific value of statistical methods and quantitative analysis abound in the present-day literature of the social sciences. Thus Professor Howard Becker in his "Systematic Sociology" says that "sociological problems are not quantitative problems at all." On the other hand, in all the theoretical social sciences considerable schools have arisen of recent years which claim that the only way in which social studies can be made scientific is by the use of the statistical method. These social scientists apparently subscribe to Karl Pearson's aphorism that "science is measurement."

Now I am not prepared to endorse either the dictum of Professor Becker or the aphorism of Pearson. It seems to me that some of the basic problems of human society are physical and hence susceptible of quantitative statement. In such cases quantitative methods enable us to state the problem in more definite terms, and indicate to us logical possibilities. Such, for example, are in the main the problems of population. But it would also seem to me that science can be measurement only when it deals with those aspects of reality which are subject to quantitative statement, and that there is perhaps no greater source of confusion in the social sciences at the present time than blind adherence to such an aphorism as Pearson's. It would seem to me that as we ascend in the scale of life the view that science is quantitative measurement of objective conditions becomes less and less applicable, not only because measurement becomes more difficult, but because the subjective element plays a larger part. Even if the subjective element is capable of certain measurements and even if it is true that whatever exists exists in some quantity or number, nevertheless, it is obvious that where subjective elements play a large part, measurement becomes of less importance for accurate knowledge because it is confined to the superficial aspects of the total situation and fails to expose the nature of the process which is being investigated. This is especially true in the social sciences and in them measurement seems to me to play a rôle secondary to other scientific methods.

If this is the actual condition in the social sciences, it explains the contradictory statements regarding the value of measurements which we find in present-day literature. It is obvious that Pearson was thinking of the physical sciences when he said that science is measurement, and it is probable that those social scientists who hold to substantially the same view have been unduly influenced by the development of methods of measurement in the physical sciences. On the other hand, it is obvious that Professor Becker, in asserting that sociological problems are not quantitative problems at all, is thinking of the systematic analysis and classification of social situations and processes which must be made before statistical measurements can be fruitfully undertaken.

But the radical reason for opening up afresh this much-discussed question of the place and validity of the statistical method in the social sciences is the rise and triumph of the cultural conception

of the human society. This new conception, which was alien to practically all social thinking a generation back, puts human social behavior in a class by itself among objects of scientific investigation; for there is no analogue of human culture in the rest of nature. As yet, however, those working in the field of social sciences have not come to see clearly that the value of the statistical method in those sciences is necessarily conditioned by the nature of human society. If the study of culture has revolutionized our conceptions of that nature, then it must also revolutionize our conceptions of the method appropriate to the social sciences.

I mean, of course, by "science" theoretical science. The knowledge which theoretical science gives us must be of a universal character. A scientific generalization is one which will hold anywhere under given conditions. Scientific generalizations in this strict sense rise above the temporal and local. They hold universally. So great is the stability of physical nature that most measurements of physical processes under given conditions do hold universally or nearly so. The question is whether such measurements are possible in human society, and if so how far can they go? Is there the same fixity or stability in social processes, so that measurements once made and correlations once established will, like those of physical nature, hold universally?

Now, the cultural conception of human society is revolutionary for the social sciences just because it emphasizes that all our social institutions and social arrangements are historical, cultural products. The social life and the social processes of the Eskimo, for example, are products of their history—of a process of invention, learning and adaptation which began in remote times and which has been continually changing down to the present. But this is equally so of the social life and the social processes of the American people. According to the cultural conception of human society, human societies are what they are, not so much through the working of natural forces as through processes of invention and learning. The whole institutional and social life of a people has been produced by learned adjustments, and, so far as we can see, will be subject to indefinite modification by invention and learning in the future. Therefore, the social phenomena which we undertake to measure by the statistical method are historical products, as much so, for example, as private property or democratic government. Such social phenomena are subject to change by further invention and learning and rarely show the stability and fixity which we find in physical nature. In other words, social reality is dynamic, while the phenomena which the physical scientist is called upon to deal with are relatively static.

Now, something of the difficulty of the measurement of social phenomena has been perceived by our greatest statisticians. We find Professor G. Udney Yule, for example, saying, "Statistical methods should be regarded as ancillary, not essential" in the social sciences.[1] To take another example, Mr. Malcolm C. Rorty, who was president of the American Statistical Association in 1930, in an address before that body,[2] demanded that statisticians be logicians and scientists in the broader sense, and only secondarily users of statistical techniques; for, he said, all statistical conclusions needed to be reached primarily through logical and experimental processes, supplemented by simple numerical and graphical analysis. He added that the verification of conclusions by means of controlled statistical methods is very rarely possible in the social sciences, and

[1] *British Journal of Psychology*, Vol. 12, p. 105. Quoted by Young, "Social Psychology," p. vii.

[2] See *Journal of the American Statistical Association*, Vol. xxvi, pp. 1–10, March, 1931.

warned against the assumption that a coefficient of correlation establishes any presumption whatever as to cause and effect relations between social variables. Thus apparently Mr. Rorty would restore logic to the supreme place in scientific methodology.

But other users of the statistical methods in the social sciences are not so careful as these leaders. Apparently many of them think that the statistical method is capable of giving measurements and correlations of universal social validity. Thus in the very issue of the *Journal of the American Statistical Association* which contains Mr. Rorty's address there is an article on "The Influence of Population Density on Crime," by a Canadian statistician, in which the conclusion seems to be reached that there is a definite correlation between population density and crime. If so, it would be hard to explain why the crime rate in Great Britain is only one tenth that of the United States, while the population density is many times greater. As soon as we understand, however, the differences in the historical culture of the two peoples, the reasons for the differences in crime rate become apparent without the use of statistical measurements. The factors which enter into the crime rate are quite evidently historical and cultural conditions and are very variable.

There is a considerable number of the less critical advocates of the statistical method who seem to hold that in the more fundamental processes of human society statistics give measurements and correlations of universal validity. For example, they seem to think that when it comes to certain biological functions these functions are the same under all conditions of culture. Thus we have the statisticians of population laying down laws which hold universally for the growth of population. They point to the logistic curve which population statistics seem to follow under certain circumstances. Similarly, we have those who argue that the more fundamental aspects of economic life are also the same under all conditions of culture, and we have economic texts which are filled with statistics, graphs and curves which are held to be true of human society, if not everywhere, at least in the long run.

Now, I am not prepared to say that there are not physical and biological conditions which hold universally for every human society of which we have knowledge, and which would, therefore, give universal correlations between these physical facts and social facts. If such correlations exist, however, they probably concern processes which are not distinctively human, but concern animal groups quite as much as human groups. But the distinctive mark of human society, and ordinarily of all that we call human, is culture. If correlations exist between physical facts and social processes, they interest us as social scientists only in the same way that we are interested in physical and biological science as a foundation for social science. They do not explain the distinctively human in social processes and conditions.

Moreover, all such correlations, the greatest statisticians are beginning to tell us, are of doubtful universal validity. Thus at one time we thought that a definite correlation could be discovered between the density of population and the death rate; but modern sanitary inventions are making any such correlation doubtful. Again, the incidence of disease and death varies so much in human societies under different cultural conditions that few, if any, correlations which will hold universally can be discovered. Again, we used to think that there were very definite correlations between the birth rate and economic conditions. But the discovery and popularization of methods of birth control have made such correlations doubtful, because the use of these methods is motivated by other cultural conditions than the economic. It might almost be said

that it is doubtful if any correlations of universal validity exist in the field of vital statistics. Correlations which are found seem to have, at most, only a relative validity, that is, relative to a given culture. But vital statistics represent the most physical aspect of the human social process; and if universal correlations can not be found in this field, we may doubt if they can be found by means of statistical measurements in other social science fields.

Let us use one more illustration to make clear the relativity of all statistical measurements, if they concern cultural appliances and conditions. The illustration is the mortality statistics of automobile accidents issued by the Federal Bureau of the Census and other statistical agencies. We notice at once that these statistics vary greatly from place to place, and if we examine them in time, from year to year. While certain correlations are discoverable between automobile accidents and the number of motor cars, the density of the population and other conditions, they do not seem to hold universally. If, for example, we get a correlation between the number of accidents and speed in driving, we find that such a correlation holds only for a given stage of the development of the automobile. A new invention may make high-speed driving much safer and the correlation disappears. Thus, it is safe to conclude that statistical measurements of human social processes are so affected by the development of culture, that they hold only for a given time and place, are relative to a particular phase of culture, and are only indirectly of value for the construction of theoretical social science.

I am not, of course, raising any question as to the practical value of statistical measurements for the guidance of social action. Just because such measurements are relative to the place and the time in which they are made, they are of the greatest practical value. The statistical method can, in a word, give us two sorts of knowledge which we greatly need for the guidance of social action. Statistical methods, when rightly used, can show us, first, what are the social facts, and, secondly, when extended in time, what are the trends in our society and civilization. Statistics thus lay a factual foundation for social theorizing and indirectly they may contribute greatly in this way to social theories which are of universal validity. As Professor Yule says they should be regarded as ancillary, not essential, in the social sciences. They become essential only when we attempt to apply our social science to the interpretation of present human society. Then we need to know to the fullest extent possible all the factors which are influencing social occurrences among us, such as births, deaths, accidents, market prices and the like. It is only statistics which can tell us accurately about movements and tendencies in present-day society. Moreover, I am inclined to think that many of the newer methods developed by statistical science, such as "sampling," are more valuable for revealing current tendencies than their critics suppose. The "straw votes" undertaken by such enterprising periodicals as *The Literary Digest* have turned out to be surprisingly accurate. It would seem that we can rely upon the method of "sampling" to discover trends in our civilization much more than what we had supposed.

But even so, a limitation of the practical values of statistics comes immediately into view. If statistics can show us facts and trends in our present society, we must remember that these facts and trends may sometimes be changed overnight by new inventions, new discoveries or a sudden change in the emotional reaction of a population. A fact is local and temporal and a trend is temporal. Both are limited by conditions of time and place. A change in culture may bring a change in the correlations which statistics reveal between local conditions

or between temporal conditions. The demonstration of a fact or the demonstration of a trend in no way shows what is inevitable or unchangeable in human society. We doubtless need more and better statistics for the guidance of social action, but we shall continue to need careful, logical interpretation of these statistics before we make them a basis for practical policies.

The utility of the statistical method in the social sciences, therefore, turns out to be very much like the utility of the case-study method. Both are indispensable for the understanding of our present civilization and social life, and these methods it is needless to say are not opposed, but supplement each other. The followers of the case-study method should make a larger use of statistics, and the students of statistics should get down to the study of concrete cases. Both methods fit in also with the historical method and supplement it. The time has surely come for every student of the social sciences to acknowledge that only a composite method, which shall include all methods of securing reliable knowledge, is an adequate instrument of research in the field of the social sciences.

So far from this being generally acknowledged, however, we find a considerable school who tell us that only quantitative methods in the social sciences are worthy of being called scientific and that the social sciences of the future will become, if not speedily, then ultimately, wholly quantitative. Thus we find one writer of this school asserting that "the new content (of the social sciences) will consist of the statistically summarized results of a large number of behavior records in all fields of social behavior." This, is perhaps, an extreme example of the attitude of the behaviorist in the social sciences, but it shows clearly the effect upon the social sciences of a one-sided advocacy of the statistical method, despite the cautionings of the great leaders in statistics. According to this view the scientific character of any text-book in any of the social sciences could be determined by simply measuring the pages devoted to "statistically summarized results," assuming, of course, that these results have been reached with meticulous care by statistical experts. The writer of this prophecy, however, forgets that all the great texts in the social sciences, from Adam Smith to the latest text in social psychology, political science or economics, have consisted much more largely of careful logical reasoning than of "statistically summarized results." And we have every reason to believe that this will continue to be so, if the positions taken in this paper are sound, in any future development of the social sciences which we can foresee.

For, to summarize, it is very rarely possible to discover in social statistics correlations which are universal, such as science in the strict sense demands. The social phenomena which we can measure by the statistical method are historical cultural products which vary independently from day to day and place to place. They can, therefore, be rightly interpreted only when viewed in the light of cultural and historical development. Statistics are indispensable to show existing social tendencies; but if they are taken in the social sciences as revealing rigid and universal correlations, or "laws," they lead to grave sociological fallacies. While we need better statistical measurements of social movements, we need more philosophical and historical insight in interpreting them.

PATHOLOGICAL ARSON

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THE losses arising out of the destruction of property each year by incendiaries reach figures of staggering proportions. Millions of dollars in values, that might otherwise be preserved for the benefit of society, are destroyed through this agency by fire.

Authorities concerned with the investigation of losses where arson is suspected are of the opinion that it is the tendency to underestimate the extent of incendiary fire losses. It is pointed out that when a fire is deliberately set, the individual responsible sees to it that he does a good job, while accidental fires may be, and often are, checked before any serious damage occurs. While 25 per cent. of all fires are not due to incendiarism, reliable estimates have placed the loss due to incendiarism and arson at 25 per cent. of the entire fire loss.

It is ordinarily supposed that the prime cause of the deliberate destruction of property arises out of the desire to defraud insurance carriers. It is indeed true that incendiarism made its appearance as an instrument for perpetrating fraud when the insurance idea was in the very process of development. In fact, the depth of degradation to which men have stooped to defraud insurance companies is appalling and little realized by others than those near the business. There is, however, a source of incendiarism that involves no moral turpitude, may strike anywhere at any time and spread death and disaster in its wake.

The records are lurid with disastrous fires, deliberately set by individuals affected with a form of mental derangement. The term "pyromaniac" as applied to those acting under an irresistible impulse to set fires is familiar to every one. The popular use of the word, however, has led to its employment oftentimes where there is no mental aberration, and for that reason the term "pathological arson" has been offered as a substitute for abnormally motivated fire setting. Under this broader heading we may include the morbid propensities which give rise to pyromania, cases of mental conflict, feeblemindedness and epilepsy. Healy defines pathological arson as "fire-setting under an abnormally conditioned impulse by a person not determinably insane."

If the form of mental abnormality which gives rise to the threat of disaster were easily recognized, then there would be no problem. It is out of the subtlety of the difficulty that the danger arises. Pyromania, for example, is one of those difficulties recognized by the presence of persistent ideas. Such troubles present themselves in many different forms. An idea rises into consciousness, and the patient is powerless to overcome it. When the idea forces itself into his mind it crowds out all others and becomes a source of great discomfort and inconvenience. These forms of mental disturbance may occur in otherwise mentally normal persons. Such ideas may be nothing more than a number or sentence or the like, forcing its way into the mind of the patient against his will, but involving no overt action. Pathological tendencies are not at all uncommon and frequently present themselves in a manner giving rise to no serious consequences.

Closely allied to the derangement arising out of the presence of insistent ideas is that involving morbid impulses. It is

this in which we are here interested. In this difficulty the uncontrollable impulse to do something takes possession of the patient's mind with such force and power that restraint seems impossible. Impulses of this type, as soon as they appear in the consciousness, may pass immediately into action. Impulses associated with intense morbid emotional states are termed morbid propensities. Here we find pyromania.

A patient suffering from a morbid propensity has an impulse to do a certain act. From the point of view of fire-setting we get a better understanding of the situation when we realize that such a patient, when acting upon a morbid impulse of this type, is not only fully conscious of what he is doing, but in addition oftentimes derives great pleasure from its accomplishment. The number of such morbid propensities is great, differing widely in their nature and character, some harmless, others a menace to life and property.

The mental attitude of the pyromaniac is illustrated by a plea presented to a judge by an individual on trial for arson. Admitting his guilt in setting the fire of which he was accused, he pleaded that when the impulse to burn overcame him, even though he knew it was wrong, he was powerless to resist. The records show that the judge sentenced the accused to twenty years at Sing Sing. It must have appeared later, however, that the case was one of mental abnormality, for the accused was transferred to the Matteawan Hospital for Insane Criminals.

The damage that a pyromaniac free in a community can accomplish is almost incalculable. There is reported an instance of a member of the fire department in a central Western city who confessed responsibility for setting twenty fires. A nurse in a hospital set fire to the building, causing sixty-five deaths. A youth in an Eastern state, charged with arson, confessed to burning thirty buildings, with losses aggregating approximately $170,000. In another town there were over fifty suspicious fires covering a period of five years. Some of the buildings were inhabited dwellings, from which the occupants had to be rescued, to save them from the fire. Over twenty of these fires were traced to the same mentally unbalanced individuals. A list of examples could be carried to interminable length. A final case will serve as typical and admirably suited to illustrate both the amount of damage a pyromaniac may do and the difficulty of his apprehension.

One fall morning two fires were discovered in a hotel located in an Eastern city. The first occurred in a vacant room, the other in a linen closet. Because of the suspicious nature of the fires state police were called in to investigate, and it was soon learned that similar fires had occurred in five other hotels in cities located near-by. A check of the registers disclosed that at the time the fires occurred there was but one guest present at every fire. Naturally, suspicion was directed toward him, and he was subsequently arrested. During the investigation this individual confessed to setting not only the five fires in question, but a great many others in other cities and in distant states. A check of fifty reported hotel fires showed that this man was registered as a guest in over half of them, and it is possible that he may have been the cause of fires that gained such headway as to make it impossible to determine the origin, as well as destroying the records.

Before leaving the case, a word about the young man is of interest. There were no peculiarities reported by the investigators that would indicate any mental difficulty other than the propensity to set fires. He was to all appearances normal, able to go about his business and

hold his job. A press notice at the time of his arrest stated of him: "He is described as a man of superior education and is employed by a reputable Chicago firm. It is apparent, the police said, that he is suffering from pyromania, and he could assign no reason for his acts beyond the satisfaction of his desire to behold destruction by flames."

Because the mental illness of the pyromaniac manifests itself in no other way than through this propensity to set fires, such individuals are extremely difficult to apprehend. They are often possessed of unusual craft and cunning, though such individuals are becoming better understood through the scientific study of psychiatrists and psychologists.

Certain characteristics of the pyromaniac are worthy of note. He is said to be almost certain not to leave the scene of the fire he has started, or if he does he will just as certainly return, because only through watching the fire he has set does he derive the satisfaction that he craves. Possessing this knowledge, investigators have come to watch for the pyromaniac among the onlookers at the fire. Then there are individuals suffering from this difficulty who show a tendency to start fires in a certain way or in certain circumstances. Such an instance was cited in the case of the young salesman who started the fires in hotel rooms. In an epidemic of tenement fires a number of them were traced to a single individual, who always started them in baby carriages left in hallways. Others are attracted to special type buildings, such as barns, schools or churches.

An unfortunate angle of this problem is the frequent failure of authorities to recognize the pyromaniac as one mentally ill. When apprehended, these individuals frequently are tried in the courts as ordinary criminals and sentenced to prison terms. There can not be the slightest doubt but that such individuals should be kept in confinement, where they can do no harm. There is no more reason for punishing them in prison than there is for imprisoning others suffering from a different kind of mental illness.

There is evidence, moreover, that these cases will respond to treatment. Naturally, the results of such treatment should be carefully watched, and the dangerous cases not carelessly released to wreak further damage. Very interesting is the report of a man who had been committed to prison for setting a fire. A cure in his case was reported, following his assignment to the task of stoking the prison furnace. Here is a case of psychological adaptation, not deliberately planned, to be sure, but none the less effective.

The fact that a cure was effected in this way throws additional light not only upon the nature of the disturbance but also upon the possibilities of systematic treatment. Psychiatrists now recognize that the chronically insane form a comparatively small group of unfortunates. They now know how exquisitely fine are the adjustments of the mental organization, and the ease with which maladjustment takes place. Pyromaniacs fall definitely into this class of the mentally ill, and are therefore not properly to be considered as criminals and incarcerated solely for punishment, frightful and cowardly as their acts actually appear.

Pyromania, however, is by no means the only form of mental difficulty giving rise to incendiary fires. In the case of pyromania, fires are set because of the presence of morbid impulses. Hence the element of motive as ordinarily considered is entirely lacking. There are individuals, however, who, lacking in character, are known to react to situations that would not cause a reaction in a normal person. Likewise, a person suffering from one of the types of mental difficulty to which the legal term insan-

ity is applied may act upon a motive which to the normal person is devoid of all logic or reason.

Burnings from individuals of this type often are caused by young men from fourteen to sixteen. They are characterized by lack of emotion or affection, and often have cruel dispositions. When apprehended there is no evidence of sorrow for their acts, even in cases where there is a loss of life of human beings. Cases are recorded where boys of this type burned a barn and sat on the fence near by and watched the struggles of the animals. Sometimes the individual wishes to appear a hero to the community, or more frequently in the eyes of some girl. A case of this kind is recorded where a youth set fire to the barns belonging to the father of his sweetheart, then seriously injured himself in playing the rôle of hero. He was later committed as incurably insane.

A certain type of the hysteric often resorts to fires as a means of attracting attention to themselves. Oftentimes, to create a great excitement, he sets fire to some public building, such as a church, a school or other important edifice. When the fire is well under way, he breaks into prominence as its discoverer. Such an individual courts newspaper publicity and poses willingly for the press. Sometimes merely the craving for excitement prompts the act, and the individual responsible gets his satisfaction, not, as the pyromaniac, from seeing the flames, but rather from mingling in the crowd. This mental type is illustrated by the case of eight members of a fire department who were charged with originating the fires to which they responded. More than forty fires over a period of four years were attributed to the group. According to the report, they took their arrest as a joke and confessed responsibility for ten of the fires which had occurred within a few months just preceding.

When surroundings have become irksome, individuals lacking in mental strength have resorted to fire as a means of relief. Persons unwillingly retained in institutions have fired them, sometimes with the idea of creating a commotion and escaping, and at others motivated by the idea of revenge against society in general, or the institution in particular. Homesickness frequently has been the cause of such fires, and those responsible have frequently exhibited great skill and cunning in concealing their connection with the crime. Again, there are recorded cases where the despondent in difficult situations have caused fires, as when a discharged porter set fire to his uniform.

The problem is important for at least two reasons. While insurers bear the brunt of the losses from fire, they are nevertheless losses from a social point of view. What is destroyed is lost forever. If a study of the pathological types that are responsible for the setting of fires will aid in their apprehension and segregation, the effort may be well worth while from the standpoint of dollars and cents.

But aside from this there is another important feature to the problem. Arson is a serious crime. Under the common law it is a felony, and so punishable. Statute law has broadened the definition of arson to make it more inclusive, and continues to emphasize its seriousness through its retention among the crimes classed as felonies. With the increasing knowledge we have in the field of psychology and with the trend toward the utilization of this knowledge in the field of law, we are learning that the actual commission of an act does not of itself constitute a crime. In the cases of pathological arson it is not easy to decide where the element of responsibility ceases. There is no abrupt line of demarcation. Justice to the individual, however, involved in the setting of fires where the motive is not clear, demands a study of his case in the light of determining his responsibility, before he is placed upon trial for the offense.

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A POSSIBLE SOLUTION OF A MAYAN MYSTERY

By Dr. C. WYTHE COOKE

U. S. GEOLOGICAL SURVEY

THE explorer of an uninhabited land is likely to think of the region in which he travels as having always been in the same condition as that in which he finds it. He is likely to take it for granted that the same kinds of plants and animals have always lived there—the same birds of the air, the same beasts of the field, the same fishes and the same ubiquitous insects. He knows, of course, that species after species has appeared, reached its culmination and become extinct; but he assumes that most of the changes in fauna and flora took place long ago, in the dim geologic past.

But the earth is not dead or dormant. Geologic processes are going on all the time that may so alter the physical features of a region as to necessitate important changes in the distribution of the species of plants and animals that inhabit it. Most geologic processes act very slowly and inconspicuously, but their effects are cumulative. Now and then there is a critical time when the effects become suddenly apparent, just as when water, heated slowly, suddenly begins to boil when its temperature reaches the boiling-point.

Changes in the distribution of plants and animals may be brought about by geologic processes that act either within the earth or on its surface. For instance, strains and stresses within the earth may accumulate quietly until something breaks and the strained strata readjust themselves, causing an earthquake. Such crustal movements may suddenly raise or lower parts of the surface of the earth, thus interfering with the long-established drainage and causing the flooding of parts of the land or the emergence of the bed of the sea. Thus Reelfoot Lake in Tennessee came into existence in 1811 as a result of the New Madrid earthquake.

Also, the normal external processes of erosion and sedimentation, always going on, may produce rather rapid changes in the environment of living organisms. A lake receiving sand or mud from streams will gradually become shallower and shallower. The silting up may continue for centuries without perceptibly affecting the kinds of animals or plants that live around or in it. But in the course of time the lake will become so shallow that plants can take root on its bottom. Some kinds of fishes or mollusks or birds or insects will be favored by this change and will multiply; others necessarily will diminish in numbers. At last, its storage capacity diminished by silting and its loss of water increased by the transpiration of plants, the lake is likely to dry up now and then. This change proves fatal to many of its inhabitants, and others move away. Finally, the once open lake becomes a bog or swamp or meadow or arid plain, inhabited by a group of organisms very different from its original population.

This is what appears to have happened in the Peten district of Guatemala since the Maya Indians founded cities there two thousand years ago. To-day the ruins of their temples and palaces stand on hills of limestone overlooking great

logwood swamps or bajos—most uninviting sites for cities. The limestone uplands upon which the Mayan cities were built are quite habitable except for the lack of water. Like many other limestone regions they contain few perennial streams. Most of the rain-water runs into sink-holes, from which it rapidly drains away through underground channels. The only drinking water to be had is found in depressions in the ground that have become floored with an impervious layer of black mud. Water collects in these natural reservoirs (aguadas) in the rainy season, but many of them dry up completely before the next rains come. Some of the Mayan cities are without any present permanent source of water.

The bajos or logwood swamps appear to be large flat-bottomed lake basins filled with black clay. Most of the water that floods them during the rainy season quickly runs off through overflow outlets. For weeks after the flood water has receded they are almost impassable because of the deep sticky mud that covers them everywhere. Later in the year they become parched and dry. They are densely overgrown by thickets of thorny trees festooned with tangled vines. At all seasons the bajos are most unpleasant places to travel through. It is difficult to imagine why the ancient Mayas should have built their cities on the banks of bajos.

If the bajos were lakes when the cities were founded the mystery is solved, for there is no more beautiful or more suitable site for human habitation within the Peten district than the shores of a lake. Most of the present settlements stand beside lakes. The lakes furnish a plentiful and unfailing supply of water throughout the year; they teem with fishes, edible shell-fish and water-fowl; they serve as highways for the transportation of farm produce and other merchandise to the towns; they are centers of health-giving recreation; and they are very good to look upon. The word Peten in the Maya tongue means, indirectly, lake. It would be even more appropriate as the name of the district if the bajos, now logwood swamps, were still lakes, as some of them probably were when the country was first occupied.

The ruins of the ancient city of Uaxactun, now being explored by the Carnegie Institution of Washington, stand on hills overlooking Joventud Bajo, an extensive logwood swamp. In 1931 I suggested that this bajo might have been a lake when the city was founded; that soil washed off the cultivated fields into the lake, filled its basin and converted it into a bajo; and that this change may have been one of the interrelated causes that led to the abandonment of the city. With the hope of testing this hypothesis and finding whether the deposits in the bajo give a clue to its early history, an 18-foot pit was sunk in 1932 under the direction of Ledyard Smith, leader of the Carnegie expedition, at a place in the bajo about a quarter of a mile from the shore. Samples of the materials penetrated in this pit were examined microscopically at the Geological Survey by Dr. C. S. Ross.

From the surface to a depth of 6¾ feet, the bajo is underlain by a bed of tough black limy clay consisting of about two thirds clay and one third lime in the form of minute crystals of calcite. The black color is due to a little decomposed vegetable matter. Under the black bed is a deposit of light-gray marl composed of nearly equal parts of clay and lime, also in the form of minute crystals of calcite. Both beds evidently accumulated in water. The clay in each gradually settled from suspension, while the particles of calcite were crystallizing from solution and falling to the bottom.

A significant fact brought to light by the microscopic examination is that although the materials cut by the pit are essentially of the same qualitative com-

position from top to bottom, the relative proportions of clay and calcite are unlike in the upper and lower beds, the upper bed containing more clay and less calcite than the lower bed. Therefore, if we assume that the crystallization of calcite continued at a uniform rate, it is evident that the rate of deposition of clay was variable, being slow at first while the light-gray marl was accumulating and then suddenly speeding up to form the deposit of tough black clay. Keeping this in mind, we may interpret the early history of the Joventud Bajo at Uaxactun as follows:

At first there was a beautiful clear, deep lake. It was filled to overflowing during the rainy season and held an abundance of water throughout the year, although its level may have fallen below its outlet during the dry season. The water that flowed into it from the adjoining limestone uplands contained a little lime in solution and held a little finely divided clay in suspension. These materials were deposited on the bottom of the lake in the form of fresh-water marl, which accumulated very slowly until the lake was only about 6 feet deep a quarter of a mile from the shore. Then something happened that greatly increased the proportion of clay brought into the lake. The rate of deposition of clay was speeded up to one and a half times its previous rate, or perhaps even faster. A few centuries of silting at this accelerated rate may have completed the transition from lake to bajo. The cause of the sudden increase in the rate of deposition of clay may have been the beginning of cultivation of the soil by newly arrived inhabitants. Some soil erosion is always going on, even beneath a virgin forest, but the rate is slow. The clearing of the forest would have permitted the tropical downpours of rain to beat upon the ground and to wash away the clayey soil of the uplands into the lakes.

Let us inquire what effects the gradual transition from lake to bajo would have had upon the human inhabitants of Uaxactun. Most important, perhaps, is the effect on the water supply. While the lake was still deep there was never any scarcity of water, and natural agencies probably kept it reasonably pure; but as it became shallower and shallower the volume of water in it became less and less and it became more and more subject to pollution. The women and children had to wade farther and farther through the sticky mud in order to reach water deep enough to fill their jugs; and finally, at the height of some dry season, there was no water to be had. Perhaps before this catastrophe took place the prudent Mayas may have thrown up dams to impound some of the flood water in artificial reservoirs, or perhaps they may have stored enough water in cisterns to supply their needs.

Then there is the effect on the food supply. No one knows to what extent the ancient Mayas may have supplemented their mainly vegetable diet with fish, but it seems hardly likely that they would have totally neglected such a valuable natural resource. Their descendants eat fish when they can get it, and they also make use of a large edible fresh-water snail. This snail, an Ampullaria, unlike the fishes, survived the filling up of the lake and still lives in the bajo, sealing itself in its shell at the beginning of the dry season and patiently waiting for the floods to release it. The lake at Uaxactun may also have swarmed with water fowl, some of which undoubtedly would have found their way into the cooking pots of the Mayas, but when the bed of the lake became baked and dry the flocks of birds must have sought other feeding grounds.

Next let us consider the effect on commerce. As long as the lake was deep enough to float a canoe, a brisk commerce was doubtless carried on upon its waters. Cargoes of corn and papayas and other fruits and vegetables were

taken from the farms along its shores to the city, and boatloads of pottery and other manufactured articles may have come from a distance for sale in the market place. Gradually navigation on the lake became more and more difficult and at times of drought ceased altogether. Finally no boats could navigate the shallow waters. Thenceforth all imported produce and merchandise had to be carried to town on the backs of plodding Indians.

The silting up of the lake must have had an important effect on the health and comfort of the people. The pollution of the water supply has already been mentioned. Stagnation of the water and the scarcity of fishes and other natural enemies must have permitted an enormous increase in the number of mosquitoes. Infectious diseases spread by bad water and insects may have taken a heavy toll from the population.

Man, even civilized man, is little less immune than other animals to changes in his environment. When living conditions in a region get too uncomfortable he moves away. The once populous city of Uaxactun is now totally uninhabited and lies buried deep in the jungle. The silence of its ruins is broken only by the howl of the monkey, the shriek of the macaw, or the crash of the falling tree. Even the lapping of the waves on the shores of the lake is now stilled, and to the cause of that stilling may perhaps be attributed the abandonment of the city by its human population.

MAN: DUST OR DEITY?

By Dr. MADISON BENTLEY
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EVERYTHING has its market price. For food and clothing we give money; for money we give our toil; kindness we repay with kindness, and to evil deeds we mete out suitable punishments. Everywhere purchase-price, price-tags, estimations of value. To be sure, the markets rise and fall, prices move upward and downward; but upon most of their possessions men manage, at any given time, to come to an understanding. Stocks and bonds, butter and eggs, dollars and pounds, lands and cattle, all have their daily quotations which advertise to you their daily values, whether you sit at this minute in Nebraska or Alabama, in Boston or Los Angeles.

But upon his own value, man has never come to a fixed conclusion. His uncertainty is obviously not due to his lack of interest. For ages he has been deeply concerned over his own proper place in the scale of earthly and celestial beings. Here he has been of two contrary minds. In one mood man calls himself a god, a spirit, the lord of creation, and counts himself only a little lower than the angels. In another mood he is a worm, a disease of the dust, a helpless infant crying in the night; he avers that he was conceived of sin, is by nature weak and vile, prone to evil as the sparks fly upward.

Are these extremes of self-valuation correct? Does man properly stand both at the top and at the bottom of the scale, fluctuating from one extremity to the other, according as his mood is of self-approval or of self-condemnation? One circumstance makes us distrustful of his double self-rating. Man's human estimations usually depend upon whether the valuer is thinking of himself or of his enemy, of his own province or of some other, of his own race or of an alien people. Men are notoriously kind to their own kind and scornful of strangers. Where can you find a race,

people or culture which does not hold itself higher than it holds all other races or peoples? A white man reared in South Carolina confessed to me that he was genuinely shocked to discover that black people contain red blood like his own. Orientals despise the upstart Westerner, whites regard the brown-skin as a savage, blacks in their own undisputed domain look down upon whites and yellows. Greek and barbarian, Latin and Nordic, German and Jew, Yankee and mountaineer, Hindu and Parsee—each is arrogant and each disparages the other. Race, color, religion, economic rivalry, unlikeness of custom and many other means of human division, all tend to set on high one's own kind and to depreciate all others.

Here operates a principle of behavior that is both fundamental and momentous. The conduct of all social animals is determined by the pattern of the group as well as by the nature of the individual itself. The provincial abroad can not act naturally. He is constrained and unfriendly. The "outside" pattern does not conform to his own provincial manners. He clings to his comfortable habit, while he despises the disconcerting conduct of the foreigner. To be just in their human values, men have to surmount this inveterate tendency, the tendency to rate high their own kind and to rate low the stranger and the alien.

But failure here is disastrous; and the more tribes, nations and races commingle, each living with all and each valuing all, the more disastrous it is. We like to think that civilization has made men objective and tolerant. But just as we flatter ourselves that it has made men of one kin, some race, religion or people rises to assert its purity or its superiority. May we hope that such a primitive and barbarous discrimination of men will presently be outlawed by a more enlightened and self-respecting judgment!

A wholesome corrective to this distortion of racial and tribal values is afforded by a wider perspective, by a view which places all human kinds together against a common background of the universe. Imagine yourself removed from the earth and looking out upon the planets with the eye of the sun. Now man and all his works and concerns shrink in the distance. His own little world spins, a grain of sand, among a group of tiny planets. Here the blazing sun is central, and man himself becomes an imagined fleck of dust.

The perspective becomes still broader and clearer when we forsake our great sun and fly to the very limits of our whole stellar group or galaxy. Now our sun is himself lost among a million suns, some of them a million times his volume. Just where our local lord of day and night stands among this great galactic host, no one is certain; although it is agreed that he (and we) are so far from a central position that thousands of years of travel, moving with the unattainable speed of light, would be required to bring him into the doubtful eminence of Central Ruler in the galaxy. Should we still retain a delusory idea of the cosmic importance of earth, of genus *homo*, of a chosen race, of a "pure stock" or of a vaunting dictator, let us project ourselves still further from the large boundaries of our galaxy, proceed for a million light-years through vacuous space and approach another stellar galaxy. This may be the famous nebula of Andromeda, as roomy at least as our own galaxy. But Andromeda is itself but a way-station on a journey which might go on for fifty, sixty or eighty million years and still not reach the most distant outposts that signal to our earth, to our most powerful microscopes, and ultimately to the seeing eye of man.

The mere bigness of this celestial cosmos, where unnumbered galaxies float in unbounded interspaces, tempts us to forget that puny man exists. At least as a

space-filler man would seem to be negligible. Even his breath-taking flights in airplane and racing-car give a comic futility to the spaciousness of this little earth. Though he whirl round and round his tiny ball in minutes or seconds, the event has no significance for his tolerant sun, and its human impressiveness is quite lost on the galaxy and on the other cosmic masses.

But mere bigness is not everything. To the recipe of man's composition went about a quarter of all the elementary substances found in the entire universe; carbon, hydrogen, oxygen, iron, nitrogen and a score of other chemical elements. He himself is a fair sample of the entire cosmos. The make-up of his body is—we may believe—far more complicated than that of any star or galaxy of stars.

When the mountain and the squirrel had a quarrel, the mountain called the squirrel "Little Prig." The squirrel replied, "If I can not carry forests on my back, neither can you crack a nut." Possibly man can, in spite of his spatial insignificance, sustain his value to himself, if not to his universe, by some great feat of nut-cracking. That would not, to be sure, sanction his contempt for foreigners and his persecution of neighbors, but it might restore his self-respect for his human kind.

Now those very men of science who have revealed the trivial character of our tiny earth and who have set light-years against the modest span of man's life are inclined just now to offset this contrast of the big and the little with quite a different kind of perspective. Physics and astronomy now tend to discredit their older mechanical notions of mass, of space and of independent motion in a given body, and they even throw doubt upon the utility of the concept of matter in a description of the world. The general result of this view of things is to replace the common scenery and activity of the universe, as we naïve earth-dwellers regard it, by mathematical symbols and formulas, by abstract concepts of quanta, electrons and wave-motions.

But who made the symbols and formulas? Why man! If man has, then, created a symbolic and abstract world, he may after all have displayed miraculous powers as a cracker of giant nuts. This possibility has so impressed the physicist that he has been led to conjecture that something like the mind of man, not matter, is the most real and the most fundamental thing in the universe. Matter he is ready to discard as illusory. Mind then comes to the top, and we find many new books on the nature of the physical world and of the mysterious universe winding up in discussions of mind-stuff, freedom of the will, and the unequalled powers of man.

Do you not see that this strange turn of affairs in the physical sciences has really put man in a new position in the cosmos? From being a mere observer of a great, self-sufficient and self-running machine, he now appears as the fountain-source of the only real stuff in the whole wide world, namely, the fountain-source of mind. No longer, therefore, is man a mere mote in a sunbeam of universal energy, a microscopic speck in a forgotten crevice of a negligible corner of existence. He is no longer merely the little end of nothing whittled to a point. He is (since his body disappears with all the other material lumber of the place) the only real stuff. He is mind. If man is not therefore a real and creative deity, you will agree with me that the physicists would make him much nearer deity than dust.

Now I do not believe that the thing is quite so simple as all that. We should not be too hasty in agreeing with the physicist when he declares "Not matter, therefore mind." From being highly sophisticated in his own field he suddenly becomes very naïve. He is much more at home among his physical facts than he is among biological and psychological facts. In his bewilderment at the

loss of his old notions and categories, he has taken refuge in a very old and fairly musty philosophy of existence. Having lost matter, he clutches desperately at mind. In reading Eddington, Jeans and other writers of the "new idealism of science," one gains the impression that these men are, for the moment, at the end of their scientific tether and are perhaps unwise to try, while in a state of bewilderment, to make a decision upon the universe and upon man's place in it.

At any rate, I doubt whether we should too hastily drag dusty man from his obscure cranny and apotheosize him as thinker, creator and universal essence. Nor need we agree with the older theories of science, which saw in man only a passive observer of the great cosmic parade. Man is, as we actually know him, both trifling and great, both puny and pompous, worm-like and god-like, mean and magnanimous, foolish and wise. If he can not grow forests on his back, engender earthquakes, sway the sun and moon in their courses and flash —a bright meteor—across the sky, he can and does weigh his own earth and many stars, make earth fertile and habitable, invent tools and build microscopes, stare into the eye of a million conglomerate suns, compute celestial times and distances, and write about all these marvelous things in strange hieroglyphics for his grandchildren to read and to revise.

And that, my fellow men and women sitting with puzzled brows throughout the whole United States, is—so far as we know—more than any planet, star, galaxy or spiral nebula has ever done. Man may be little, but he is, in his way, also terribly clever. Though he can not alter the eternal course of the galaxies, he can pry into their secrets with a vast and intelligent curiosity and he can move in imagination through the endless aisles of space. If not a god, at least no ordinary worm of the dust!

BETWEEN THE STARS

By Professor **OTTO STRUVE**

DIRECTOR OF THE YERKES OBSERVATORY OF THE UNIVERSITY OF CHICAGO

VISITORS to an astronomical observatory almost invariably ask the question: "How far into space can you see with your large telescopes?" The answer is not as simple as it might appear, because the extent of our vision is greatly reduced during the daytime, while at night it reaches far out into space among the stars and beyond the confines of the Milky Way system of our galaxy. Even at night our vision is limited, not only by the insufficiency of light from distant objects, but also by a faint glow which covers the night sky and makes it impossible for us to observe or photograph the most distant stars with powerful telescopes and sensitive photographic plates.

Let us see why our vision is so much impaired during the day. Every one has noticed that terrestrial objects, such as mountains, a few miles away, have a bluish and indistinct appearance. Even directly above us, on a perfectly clear day, an aeroplane looks hazy and indistinct at an elevation of a few thousand feet. The explanation of this lies in an interesting phenomenon known as scattering of light, with which every driver of a car has had practical experience. When the sun beats down upon a dusty windshield the driver's vision is impaired and the road ahead is scarcely visible. But if the sun disappears behind a tall building or a cloud passes over it his vision is at once improved. He is no longer aware of the haze produced by the dust on the windshield, and distant objects stand out almost as

clearly as if he were looking through a clean piece of glass. This simple observation proves that the dust on the windshield does not act as an opaque screen, for if it did it would reduce one's vision in the shade as well as in the sun. What happens is that when the light from the sun strikes the dust particles a small fraction of it is scattered in all directions and some of it enters the eye of the observer and falls upon the same part of the retina upon which is focused the image of the road. This reduces the contrast and makes the outlines of the object indistinct. As soon, however, as the rays of the sun are shut off from the dust there is no scattering of light and consequently no reduction in contrast.

This is just what happens when one looks out into space on a clear day. The earth in its motion through space is surrounded by a screen of very small particles. Every molecule of air and every particle of dust scatters some sunlight and throws it into the eye of the observer where it overlaps the images of stars and renders them indistinct. Just as soon, however, as the sun disappears below the horizon at sunset, the scattering effect is reduced and vision is improved. Here again the particles of air and dust do not act as a screen of opaque matter, and when the effect of scattering is removed the observer is at once able to distinguish the light of the stars and nebulae, so that, instead of noticing an appreciable reduction in vision at an elevation of a few thousand feet, he is now able to distinguish objects which are far away from the Solar System.

The brighter stars become visible to the unaided eye; then as the sun moves lower and lower under the horizon fainter objects appear, and finally, when the sun has reached a point about 18° below the horizon we are able to distinguish distant galaxies which are so far away that light traveling at the rate of 186,000 miles per second has been on its way for millions of years. The sky has now reached a constant amount of faint illumination which it retains throughout the remainder of the night.

The background of the night sky is by no means devoid of all light. There are the stars which send their rays in all directions, and some of the starlight is scattered by particles of air and dust in our atmosphere. Astronomers have computed that this source of scattering is not appreciable, so that even our most accurate instruments of measurement would fail to record it. Why, then, is the night sky not black between the stars? On a clear moonless night the sky is faintly luminous, as every one can easily prove to himself. In fact, there is so much light that trees and other objects are clearly outlined as black shadows on the grayish background of the sky.

The ratio of the amount of light coming from the night sky to that coming from an equal area of the daylight sky can be determined by a simple photographic procedure. If we expose a plate, in an ordinary camera, to the blue sky during the day, with the shutter set at 1/1000 of a second, upon developing the plate we will find that the sensitive film is uniformly darkened. Then, if we point the same camera at the night sky and gauge the exposure time by trial so as to obtain the same degree of blackening on the plate, we find that it would take about ten hours to get the required result. The ratio of the brightness of day sky to night sky will be in proportion to the two exposure times. Ten hours divided by 1/1000 of a second gives approximately 40 million times.

The source of the illumination of the background of the night sky has not yet been completely solved. We know from the work of the Lowell Observatory at Flagstaff, Arizona, that a part of it is produced in our own atmosphere, though the physical phenomenon giving rise to this part is not scattering of starlight or of sunlight within our atmosphere. The

spectroscope has revealed that this atmospheric illumination of the night sky consists of rays of light of certain distinct colors, not of a mixture of all colors of the spectrum. It is possible that the so-called cosmic rays, so thoroughly investigated in recent years by Dr. Millikan, of Pasadena, and by Dr. Compton, of the University of Chicago, when hitting the molecules of the air cause them to emit feeble rays of light which are observed by us as a general illumination of the night sky.

However, astronomers believe that the spaces between the stars are not absolutely empty. The spectroscope is the instrument which 28 years ago proved that atoms of calcium vapor were traveling in all directions through interstellar space and since then atoms of other elements have been discovered to be present in all parts of our galaxy. The question arises whether starlight is scattered by these interstellar atoms, thus adding to the illumination of the background of the night sky, as the scattering atoms of our own atmosphere add to the illumination of the day sky. The answer depends upon whether there are enough atoms in space. Careful measurements have been made at the Yerkes Observatory of the amount of gaseous matter between the stars. The result is startling. Imagine a cubic inch of ordinary air drawn out into a column long enough to reach one of the more distant stars of the universe. To be exact, imagine that the column is 15,000 light years long, retaining of course its cross-section of 1 square inch. Let all the atoms which formerly occupied our cubic inch of air be spread uniformly throughout the column. The resulting density of matter will be that of interstellar space.

It is not probable that this small amount of gas would scatter enough starlight to add appreciably to the illumination of the sky. There remains the possibility that in addition to gaseous atoms interstellar space may contain particles of dust. Numerous observations have been made to prove whether such dust actually exists. It was found that distant stars are usually redder in color than those which are not so far away. Now it happens to be one of the properties of scattering by very small particles that a beam of light passing through the dust is reddened, while the scattered light is made bluer. Thus the scattered sunlight appears as the blue of the daylight sky; every one has noticed this effect: when the sun is near the horizon it appears brilliantly red, while the sky overhead is blue.

The fact that distant stars are redder than near-by ones might simply mean that the light from distant stars passes through more interstellar dust than does the light from the closer stars. The transmitted beam of starlight is depleted in violet and blue colors, and remains rich in red light. The scattered radiation, which comes to us as the general illumination of the night sky, must consequently be blue in color. Observations are now being planned at the Yerkes Observatory to determine the color of the night sky. Our visual sensations give us no information concerning this point, because the human eye does not distinguish the colors of very faint objects. In the meantime we may consider the hypothesis of interstellar dust as probable, though not as definitely established. A German astronomer at the University of Breslau has recently computed the number of dust particles per cubic centimeter of space required to produce the observed amount of reddening. His conclusion is that there should be one dust particle for every 500 cubic centimeters. I suppose this would indicate that our galaxy is a dusty place in which to live!

THE SCRIPPS INSTITUTION PIER AS A MARINE OBSERVATORY

By Professor WINFRED EMORY ALLEN

SCRIPPS INSTITUTION OF OCEANOGRAPHY, UNIVERSITY OF CALIFORNIA

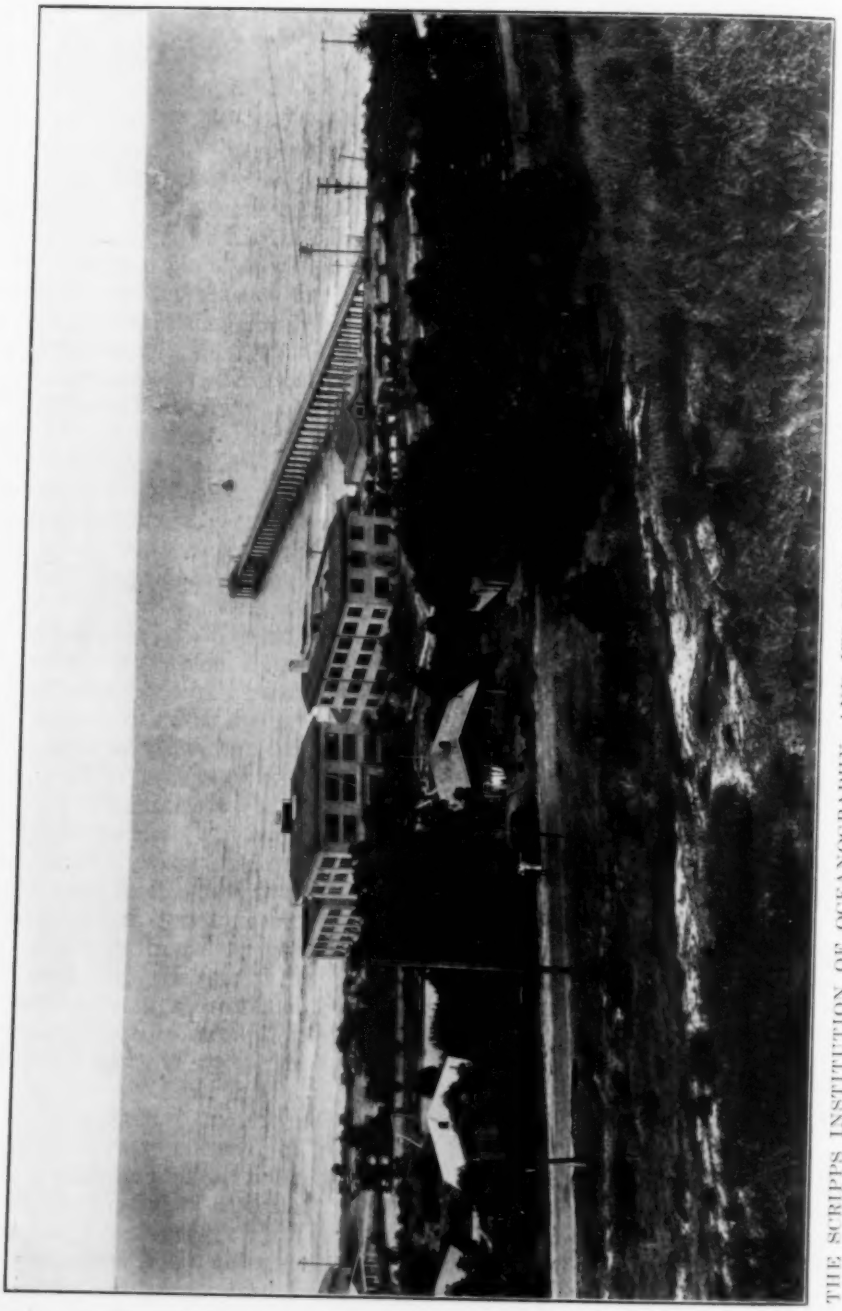
THE pier of the Scripps Institution of Oceanography of the University of California at La Jolla, California, extends into the open ocean to a thousand feet from shore. If a structure similarly extended a thousand feet into the air, it would be furnished with equipment of many kinds at fabulous cost and used for making observations in astronomy or meteorology with a corps of expert observers in *constant* attendance. As matters stand the institution pier is a partially dilapidated structure, carrying *relatively* little equipment and visited only for short periods daily for routine observations by a few employees, although much less is known positively about the ocean than is known about the solar or sidereal systems or about the ocean of air.

Aside from the records of a U. S. Coast and Geodetic Survey tide gauge and of a water thermograph, no continuous observations of any kind are made at the pier, other physical as well as the chemical and biological data being obtained from observations rarely more frequent than once in twenty-four hours. Even so, it seems probable that the Scripps Institution pier is unique amongst piers all over the world in respect to the number of different ways in which it is used for scientific investigation of the sea.

For some strange reason, direct and continuous observation which is considered essential for investigations in both astronomy and meteorology seems to be regarded as a matter of indifference for oceanography, which presents problems more intricate and difficult than either of them. Indeed the attitude of the scientific élite appears to be that the ocean can be studied most satisfyingly in one of three ways: First, by chasing across or around it with a big expedition taking transient observations at intervals of some hundreds of miles; second, by ignoring it altogether and retiring into a laboratory to perform "controlled experiments" from which all possibility of ocean influence has been removed; third, by conducting research in some science related to or connected with oceanography under the expectation that familiarity with that science will yield some knowledge of oceanography traceable through the connection.

Like any other of the common run of scientific men, I hold to the view that the way to learn about anything is to go to it directly, get as much contact with it as possible, and study it as much as possible in the conditions of its natural existence. That accounts, in part, for my own interest in observation and in the pier as an observatory. However, it is probably true that a still more important part in stimulating and holding my interest is to be found in the infinite number of fascinating problems suggested by conditions and occurrences observed from the pier, and in the surprisingly striking single features which may appear at any moment.

For the present I shall neglect the results of my routine experiences in use of the pier for the sake of telling about some of the surprises which have come to me in the fifteen years since I first began to visit it regularly and frequently. In that time I have visited the Scripps Institution pier five or six thousand times, usually remaining on it not more than



THE SCRIPPS INSTITUTION OF OCEANOGRAPHY, AND ITS PIER EXTENDING A THOUSAND FEET INTO THE OPEN OCEAN

one hour, or the time necessary for making my collections of microscopic or sedentary plants and animals. Presumably an observer in constant attendance might have seen a much larger number of surprising things than I have seen in the limited time.

For pure astonishment, I think I was never more affected than I was at the time that I idly glanced at a pelican in gliding flight about fifty feet above the water and noticed something like a three-foot length of garden hose drop and hang dangling loosely from between his shoulders. In a moment I was little less astonished when I saw him reach a foot forward and scratch the middle of what I then recognized as his head and neck hanging directly downward. After relieving the local irritation the head was lifted to the usual position above his back and the bird glided calmly onward with never a hitch or halt in his steady progress.

The California brown pelicans have also presented to me two less exciting puzzles, one of which I think I have partly solved. The latter is the puzzle of the half turn in diving. It took about six years of observation to satisfy myself on that point, but I finally became convinced that a bird plunging into the water while headed south makes a side sweep of his pouch just after striking the surface, and that this move to net his fish brings him up facing north as he rises above water again. In one case I saw the pouch distended like a football just after a dive at the end of the pier and on two other occasions I have seen it partly distended. The other pelican puzzle has never approached a satisfactory solution. It is as to why a pelican should try to perch on the wire (smaller than a lead pencil) stretched along above the pier rail. I have seen this kind of perching tried several times, although the pelican is not a perching bird and has no equipment for holding to a slender perch. In one case a pelican persisted in trying for a period of about twenty minutes. He was close to the pump house, from the window of which I chanced to notice him alight, so I was able to time him and to watch the details of his performance. In order to balance on the wire he had to use his wings. Every few seconds after getting a standing balance he would try to fold them and settle into perching position. This would cause him to lose balance and teeter back and forth with wings gently flapping until he was balanced again. I have often wondered if it amused him to see if he could perform the feat of perching on the wire in spite of his lack of fitness for it.

Another interesting thing about pelican behavior is his series of efforts to keep a gull from stealing his catch after a dive. Often when he comes to the surface and raises his head to let the water drain from his beak a gull is at his side picking at the fish seen between the edges. The pelican immediately starts paddling with one foot to swing in a short circle, the gull paddling desperately to keep up, and so they go until the water has drained and the pelican is able to throw his head up to swallow the catch. Sometimes two or more gulls combine and by getting on both sides of the pelican they prevent his circling movement. In that case they are likely to get some of his catch by snatching it through the slit at the edges of the beak.

Only a little, if any, less astounding than the pelican neck scratching in flight was my only acquaintance with a thresher shark. I was making my plankton collection one morning when a noise attracted my attention to the water a little way from the pier. I turned too late to see anything but the agitated surface, but in a moment later there was a splash and flurry near the same spot in the midst of which something like a human arm seemed to be thrust above the surface and to disappear too quickly for

me to get any clear idea of its form and size. I was still wondering about this peculiar exhibition when I thought I saw a "sand shark" about five feet long swimming rapidly toward the pier at the surface of the water about fifty yards away. A little later I could see that it was chasing a fish of about a foot in length. While watching the chase I saw the shark dart past the side of its victim and then make the water boil with a whip-lash stroke of its tail at the little fish. I then saw that it was a thresher shark and knew that the arm-like apparition above the water had been its tail thrown through the air in making a stroke. The small fish seemed to be badly dazed by the fierce stroke I saw so clearly and was swimming less rapidly in a crooked course when another stroke of the thresher's tail stunned it and it turned over on its back, struggling feebly. The shark rushed at it with open jaws, but just before seizing it he appeared to be frightened by the drip of the water from my collecting apparatus only a few feet away. So he turned and swam off. The injured fish floated helplessly for a while, but it finally revived and swam slowly away.

An auklet and a flounder were the actors in another scene so strange that I could hardly believe my eyes. I was just going on to the pier one quiet morning and had got beyond the surf when I noticed a Cassin auklet swimming toward the pier on the south side. I stepped to the rail to watch the little fellow paddle out of sight and I was just in time to see him rise off the water in a great splash and flutter and dart off in headlong terror. In the instant that he cleared the water a large flounder leaped through the air in pursuit and its snapping jaws missed the bird only by inches. I have known about birds catching fish most of my life, but this is my only observation of a fish trying to catch a bird.

On a few other occasions auklets have participated in interesting performances. At several different times I have watched Cassin auklets swimming under water, using their wings entirely for the swimming and their feet and tails for steering and control. Once or twice these little fellows have given excellent exhibitions in chasing small fish about the pier, but the best I ever saw was given by a Rhinoceros auklet at the end of the pier one morning when the water was a little rough. He was chasing fish around the piling and sometimes I was sure that he was going to be crushed as he darted into the swirl of a passing wave around a pile with wings full spread and beating as though in air. But he always came out all right, and he caught fish, too.

Some years ago, when sardines were more abundant near the pier, I often saw loons working on a school, but I never saw a fish caught by one of them. If the loon started for them at the side of the school a lane opened through it with sardines on both sides apparently at exactly equal distances from him. If he dived and came up from below the school an exact circle would be formed by the fish with the loon at the precise center. It seemed that so many fish were at the same distance from him in different directions that the bird could not decide which individual to chase. He could swim faster than any one of them, although he used his feet only in swimming.

Although I did not see it myself, it is surely appropriate to mention in this connection the killing of an octopus by a sea-lion, observed from the pier by Professor W. R. Coe, of Yale University, some years ago. The octopus was too large to be killed and swallowed easily, and the sea-lion had to spend considerable time in getting it disabled. Whenever he seized it its arms would twine about his head and he would have to shake himself vigorously in order to dislodge it. At every opportunity he

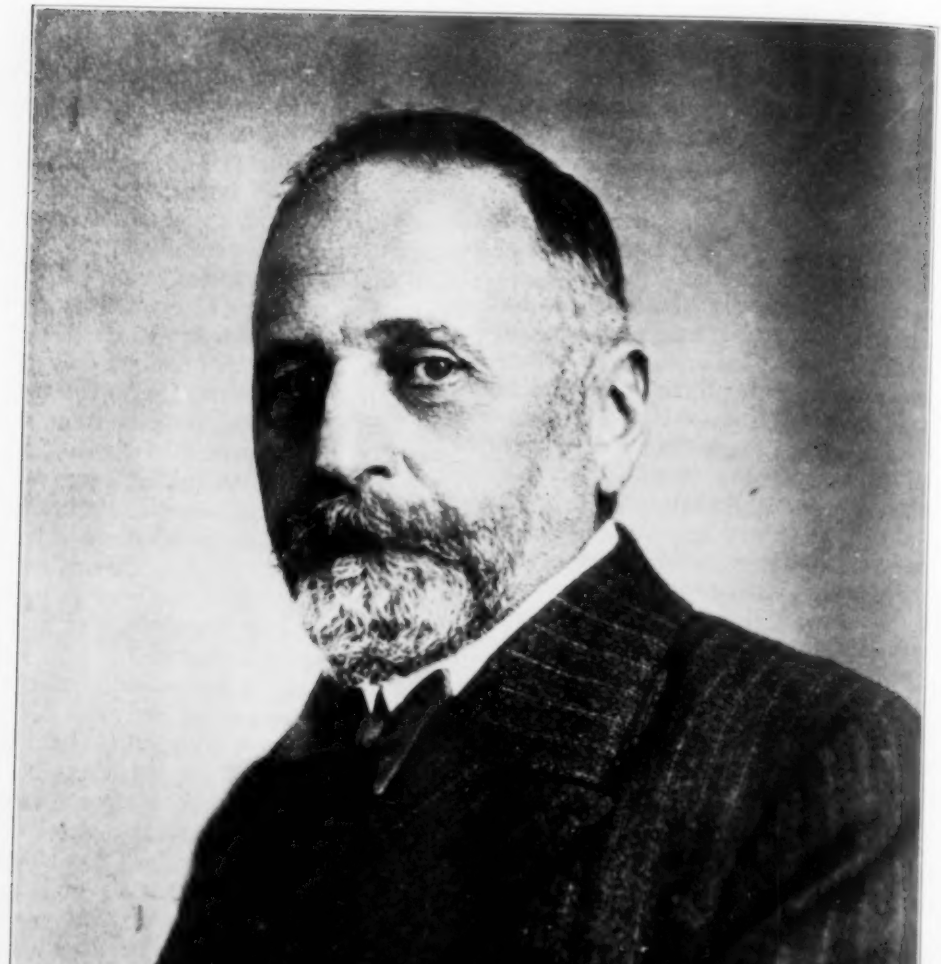
would shake it and toss it into the air until it was finally disabled to an extent that ended resistance.

Certain other rare sights have been less exciting because developing more slowly or because of being less conspicuous. Neither sea-lions nor porpoises have been abundant in recent years. About ten years ago two herds of sea-lions could be seen every morning near the pier for several days, each herd consisting of about fifty individuals. Some years ago porpoises frequently came near the pier, and I once saw a school which I estimated as covering about one fourth of a square mile in area. It paraded up and down seaward from the pier for hours. Since then I do not recall seeing more than four or five porpoises at a time and that rarely.

About ten years ago siphonophores were seen drifting past the end of the pier in great abundance for one day and in considerable numbers on two other days. I have noticed a few specimens at only one or two other times. About 1920 I saw a school of mackerel pass the end of the pier one morning. The fish were swimming all in the same direction and as close together as possible and the school extended as far as I could see from the pier. It took about a half hour to pass. I once saw "sand sharks" so thick alongside the pier that I could not have thrown in a line without hitting one. I have rarely seen more than four or five at a time on other occasions. In 1924 the dinoflagellate *Prorocentrum micans* was so abundant near the pier for a week or more that the water was colored reddish brown. It is the only case of "red water" in sight of the pier in the fifteen years of my connection with the institution.

Some of the things I have mentioned seem remarkable or important to me because they were striking performances of individual animals, showing in the first place that it is practically not possible to imagine what an individual animal can or will do or how it will do it, and in the second place that one can only get acquainted with nature by actual contact and observation. Others seem remarkable and important because they show that conditions in the ocean are constantly changing, sometimes allowing populations to exist in what we call a normal state or in equilibrium, and sometimes changing so that strange populations come into prominence or even gain a temporary ascendancy.

The problems of individual performance which I have noted are most fascinating to me, but the problems of shifts or of maintenance of populations in particular locations or regions are the ones which seem most important or at least most urgent. At any rate, I hope that I have helped to show that a pier is an important observatory and that piers deserve more use as such than they have ever had.



DR. RICHARD WILLSTÄTTER

THE PROGRESS OF SCIENCE

RICHARD WILLSTÄTTER, WILLARD GIBBS MEDALIST FOR 1933

RICHARD WILLSTÄTTER was born in 1872 at Karlsruhe and there received his early training, which was continued at Nürnberg and at Munich. At Munich he was known to his laboratory mates as the "little Beilstein" because of his phenomenal grasp of organic chemistry. He soon attracted the attention of Adolph von Baeyer, who made him assistant, privat-dozent and then extraordinary professor and head of the organic division.

Willstätter's first independent work resulted in the solution of the structures of atropine and cocaine and other physiologically active materials, including sparteine and related alkaloids. His first private assistant was an American, C. S. Hollander. His work in this period laid the basis for all modern studies in synthetic local anesthetics which lack the habit-forming properties of cocaine.

In 1902, at the age of 30, he was called to Zurich where he started work on the chlorophyll problem with the aid of a large group of students and assistants from all parts of the world. During his years in Switzerland, he made more progress toward unraveling the structure of chlorophyll than had all previous workers. He showed conclusively that the parent substance of chlorophyll is the same as the parent subst. nce of hemoglobin. He thus showed that nature had used the same fundamental material, etioporphyrin, to make the green coloring matter of plants and the red coloring matter of blood, by combination in one case with magnesium and in the other with iron; to give substances which, in one case, convert carbon dioxide to oxygen and complex organic material and in the other carry oxygen to living animal tissues. These studies laid the foundation of the work of Hans Fischer and of Conant.

During his studies of chlorophyll, Willstätter became interested in the other coloring matters of plants and opened up the fields so brilliantly developed in the carotinoids by Karrer and by Richard Kuhn and in the anthocyanines by Robert Robinson.

In 1912, Willstätter became director of organic research at the Kaiser-Wilhelm Institut. Here he carried out his most important studies on the coloring matter of flowers. Here again he showed the surprising unity of nature. For instance, the blue of the cornflower and the red of the rose were shown to be caused by the same pigment, cyanidine, in acidic and basic media, respectively.

At the outbreak of the world war, Willstätter took up aviation but was instructed to continue his laboratory studies. Although he worked on war problems such as the use of "hexa" in gas masks, most of his efforts continued in the field of the flower colors.

In 1915, he was called back to Munich on the death of his first teacher, von Baeyer. In 1918, Willstätter started his researches on enzymes, the organic catalysts responsible for life processes. In this tremendously difficult field, he has laid solid foundations which have been developed by a small but active group under his leadership at the Laboratory of the Bavarian Academy of Science since 1925 and by several of his former students, among whom Waldschmidt-Leitz, of Prague, is preeminent.

Willstätter is the holder of many scientific honors. In addition to the Nobel Prize in chemistry, he has received the Faraday Medal, the Prussian Order pour le Merite and honorary degrees from many universities. He has visited the United States in 1895 and 1927. Among his former students who have become prominent in America are Roger Adams, E. K. Bolton, A. S. Burdick, Michael Heidelberger, C. S. Hollander, C. D. Lowry, Jr., and Jean Piccard.

F. W. BREUER and FRANK C. WHITMORE
STATE COLLEGE, PENNSYLVANIA

HYDRO-ELECTRIC DEVELOPMENTS IN SWITZERLAND

In Switzerland, the country of the "white coal," as electricity is called there, another important step in the electrification of the country has been accomplished by the construction of a large seasonal storage plant, the Oberhasli Hydro-Electric Development, above Meiringen in the Bernese Oberland. Construction work on the first step of this huge project was completed recently and the Handeck Generating Station turned over to regular operation last fall.

GRIMSEL LAKE IN THE BERNESE OBERLAND

IT HAS BEEN CREATED BY THE CONSTRUCTION OF TWO DAMS, THE SEEUFEREGG DAM IN THE FOREGROUND AND THE SPITALLAMM DAM IN THE CENTER OF THE PICTURE.

The entire development utilizes the precipitations as well as the melting water of a total area of forty-three square miles, formed mostly by the glaciers of the picturesque "Bernese Oberland." Since 95 per cent. of the annual natural flow of water takes place during the six summer months, it was essential to create huge storage basins, to have the water collected during the summer available for carrying the high peak of power demand during the winter. Nature offered very favorable conditions, and engineers found it practical to create two large artificial lakes. The larger, Grimsel Lake (Grimselsee), has a storage capacity of three and a half billion cubic feet, while the smaller, Gelmer Lake (Gelmersee), has a capacity about one seventh as great. The total storage capacity of these two lakes corresponds to 230 million kilowatt-hours.

The Grimsel Lake has a surface of twenty-seven million square feet and a total length of approximately three

MOUNTAINS IN THE BERNESE OBERLAND
WITH GRIMSEL LAKE IN THE FOREGROUND.

miles. It is formed by two dams, the Seeuferegg Dam and the Spitallamm Dam. The former is the outstanding feature of the entire development, due to its dimensions, and only those familiar with the climatic conditions at an altitude of 6,300 feet above sea-level know how to appreciate the difficulties under which construction work was done. Due to the extreme severity of the winter, work could progress only during a few months a year.

The following figures may give an idea of the size of the Spitallamm Dam,[1] which at the present time is the largest in Europe: height above bottom of foundation, 375 feet; radius, 295 feet; length, 850 feet; amount of concrete, 12,000,000 cubic feet.

The water accumulated in the Grimsel

[1] The height of the Hoover Dam, in the Colorado River, is more than twice as great; its capacity is nearly 300 times that of the Spitallamm Dam.

THE INNERTKIRCHEN TRANSFORMER STATION

Lake is conducted through a horizontal tunnel to the Gelmer Lake and from there by means of a steel tube pressure line, eight feet in diameter and 3,700 feet long, to the Handeck Generating Station. The tube covers a difference of altitude of 1,750 feet with a maximum inclination of 72 per cent.

The problem of delivering the power from the Handeck Station to the load center presented serious difficulties. On account of the large number of avalanches coming down in the neighborhood of the generating station every winter, it was not considered safe to use high tension overhead lines, but it was finally decided that a reliable supply could be obtained by means of underground cables. Thus a special cable tunnel over three miles in length has been built to connect the generating station with the village of Guttannen. The power is stepped up at the generating station from 11,000 volts to 50,000 volts and is transmitted through cable circuits to Guttannen and from there by overhead lines to the Innertkirchen Transformer Station. The cable tunnel has been built large enough to permit the circulation of a small electric car which is the only means of communication during the winter season between the generating station and the villages in the lower part of the valley.

As a future extension of this development it is planned to collect the water at the turbine outlets of the generating station and to conduct it by means of a system of tunnels and pipe lines to another generating station which will be built near the present transformer station. The additional water would more than double the capacity of the hydroelectric plant.

THE USE OF THE DIVING HELMET IN BIOLOGICAL STUDY[1]

The use of the diving helmet in biological study was first introduced by the late Dr. Alfred G. Mayor, at the Tortugas Laboratory of the Carnegie Institution of Washington. Dr. Mayor and his associates used the diving helmet extensively, not only at Tortugas, but also around islands of the South Pacific. Dr. William Beebe has also employed the helmet for his studies of the submarine fauna in Haiti and Bermuda.

The form of helmet which these zoologists used was one which had been devised for work around yachts where it was necessary to go down under the boat to make examinations and repairs. It is so simple a device that it seems surprising that it has not come into more general use. It consists essentially of a brass hood with a glass front which fits over the head and rests on the shoulders of the diver and is held down by lead weights which are attached on the front and back sides. From this hood an ordinary garden hose runs to an air pump located in the boat. The person who is about to go down to examine objects under the water stands on a ladder which is let down from the side of the boat, and others in the boat place the helmet over his head as shown in Figs. 1 and 2. He then descends the ladder to the bottom as the man at the pump forces air down into the hood, the excess bubbling up around the shoulders and chest. With a long hose the diver can wander around for considerable distances. His hands are free and he can carry a basket or bucket with him and place specimens in this, or he can sit down under water and make sketches or notes on a zinc pad as Dr. Beebe is shown doing in Fig. 3. He can also take down a specially devised moving picture camera which is enclosed in a water-tight brass box, as shown in Fig. 4, and can thus make motion pictures of fishes and other objects at any depth to which sufficient light penetrates. In tropical waters it is pos-

[1] Photos by Dr. William Beebe.

FIG. 1. PLACING DIVING HELMET OVER THE HEAD OF A PERSON ABOUT TO DESCEND.

sible to take good photographs at a depth as great as fifty feet or more; but in general the diving helmet is used in water not more than thirty feet in depth, owing to the discomfort which comes from the pressure of the water on the chest of the diver, or the pressure of the air within the diving helmet. Under water photographs at a depth of twenty to thirty

FIG. 2. DIVING HELMET IN POSITION OVER THE HEAD OF THE DIVER.

FIG. 3. DR. BEEBE SITTING UNDER WATER ON A CORAL REEF AND MAKING SKETCHES AND NOTES.

feet in clear waters of Bermuda are perfectly feasible, as is shown in Figs. 5 and 6.

The type of diving helmet shown in Figs. 1 and 2 is somewhat more complex and expensive than is absolutely necessary. Helmets have been made for the Bermuda Biological Station by an ordinary coppersmith, which are just as useful and much less expensive than the type shown. Indeed some boys in Bermuda have used an ordinary wooden box with a glass front, which is notched at the ends to fit over the shoulders and from which a garden hose runs up to a cheap air pump. Such a box must be heavily weighted to hold it down on the shoulders when one is submerged, but it serves the purpose of submarine observa-

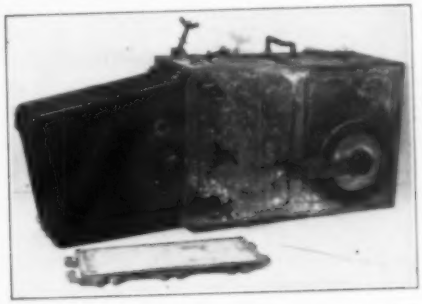


FIG. 4. CAMERA AND BRASS BOX USED BY DR. BEEBE FOR UNDER WATER MOVIES.

FIG. 5. UNDER WATER PHOTOGRAPH OF BRAIN CORAL, SEA FANS AND REEF FISH.

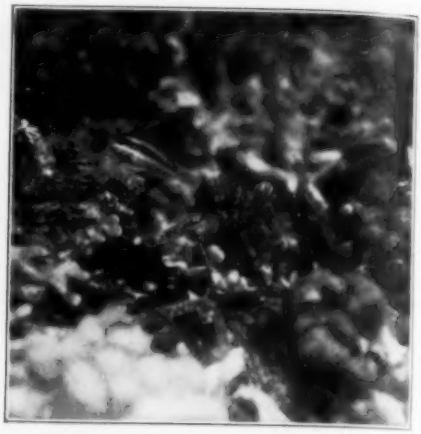


FIG. 6. UNDER WATER PHOTOGRAPH OF REEF FISH, TUBE WORM AND LIVING CORAL.

tion almost as well as an expensive brass helmet. A good air pump is the usual two-cylinder beer pump, but almost any force pump will serve.

Such a helmet is of decided value in examining submarine objects which stand at a little distance above the bottom. It is one of the disadvantages of this helmet that one must keep it in a nearly vertical position, since otherwise air would escape and water would enter. One of the peculiar beauties of this instrument, however, is that if any accident happens it can be thrown off readily and the diver can come up as he would if he had dived without any helmet.

EDWIN GRANT CONKLIN
PRINCETON UNIVERSITY

EPIDEMIC ENCEPHALITIS

THE word "encephalitis," from its etymology, means simply inflammation of the brain, and can be used to designate many different varieties of this condition. About the end of the world war there was recognized a form of encephalitis occurring in groups of cases and usually characterized by apparent drowsiness or lethargy. This form was therefore called "lethargic encephalitis" or, in popular parlance, "sleeping sickness." The latter term, however, already had another meaning; it was the name given to an entirely different condition, a disease confined to tropical Africa, caused by a microscopic one-celled organism (trypanosome), and conveyed by the tsetse fly. The tendency now is to abandon the term "lethargic encephalitis" in favor of the "epidemic encephalitis," because a considerable number of the cases show excitement and increased activity rather than lethargy, and because the grouping of the cases is often such as practically to constitute an epidemic.

In many places and at most times, nevertheless, the disease has occurred diffusely, without special tendency toward any particular grouping or epidemic prevalence, and even in epidemics the cases have been, as a rule, without obvious relation to each other. This has been particularly true in the United States, the largest aggregations of cases at any one time being where one would expect them—in the largest city, New York. Here they amounted to over 500 during the months of February and March, 1923, but at every season and in

every place the toll of cases went on, causing more deaths in most years than poliomyelitis (infantile paralysis). The proportion of those afflicted who died is difficult to discover; for in a disease occurring in such a scattered fashion the numbers of those stricken are not so well reported as are the deaths, but probably the death rate among those who contracted the disease would amount to 20 per cent. or more. Striking nervous and mental troubles followed in some of the cases, so that the disease came to be one of the most dreaded of acute infections.

From July 31, up to September 14, 1933, there were reported in the metropolitan area of St. Louis 800 cases of epidemic encephalitis with 144 deaths, an indicated case fatality rate of 18 per cent. Cases of apparently the same inception have been reported from other cities in Missouri and neighboring states, but it is to be noted that so-called epidemic, or lethargic encephalitis, and encephalitis not otherwise designated have a yearly incidence throughout the entire United States similar in magnitude to poliomyelitis as judged from mortality statistics, usually without the marked seasonal and yearly fluctuation of poliomyelitis.

Cases of lethargic encephalitis occur yearly in St. Louis, the heaviest preceding incidence having been in 1919, 1924 and 1932. Relatively fewer epidemics of this disease have been reported in the United States than in other parts of the world, the disease in the United States being apparently sporadic or endemic. Such outbreaks as have occurred in this country have previously been, as is usual elsewhere, in winter or early spring.

The clinical picture of the St. Louis outbreak is that of a general febrile disturbance, often with gastro-intestinal symptoms such as vomiting, constipation or diarrhea; evidences of cerebral involvement—an apathetic or immobile facial expression, usually somnolence, stupor, coma or delirium; usually a moderately stiff neck, with headache, which is often the first and most pronounced symptom, and other pains, as of the abdomen or legs; tremor and catatonic semi-rigidity are common in the more severe cases. Tendon reflexes, such as those of the elbow, knee, ankle and superficial reflexes tend to be irregularly diminished or absent, and to vary from day to day. Some patients are very restless and have to be restrained. Irregular paralysis may occur. Many cases are less typical, but in this outbreak the doubtful cases have usually been found to be positive by spinal puncture and further course or by necropsy. The triad of symptoms is a febrile course, evidence of cerebral involvement and mild meningeal signs. The duration of the fever stage is irregular—the temperature may be normal in a few days. Probabilities as to sequelae can not be stated at present. The milder cases which have recovered so far are apparently restored to good health.

Pathologically the lesions are of the same nature but are at a higher level and more diffused than in the usual cases of lethargic encephalitis, the cortex is involved and there is no tendency toward special localization in the central system, such as the basal ganglia and the brain stem.

The outbreak which most closely approaches this is that which occurred on the western side of the Inland Sea in Japan in 1924, and described by Kanoko and Aoki in 1928 in *Ergebnisse der inneren Medizin und Kinderheilkunde*, Vol. 34, p. 342.

The incubation period is uncertain. There are indications that it may be five to twelve days. The onset is usually fairly sudden, that is, covering not more than one to three days.

Dr. Margaret Smith, a pathologist working with the St. Louis Committee, announced to the St. Louis Medical Society on September 1 that she had found, in over half the specimens examined, a microscopic formation known as "inclusion bodies," in kidney cells.

Such a formation is common in diseases caused by germs small enough to pass through porcelain filters, and therefore called filterable viruses, and this particular finding may help to identify fatal cases of the disease outside the present epidemic focus.

A report on September 8, to the Metropolitan Health Council of St. Louis, of an attempt to transmit encephalitis to monkeys, by R. S. Muckenfuss, assistant professor of medicine, Washington University, and Charles Armstrong, Surgeon, U. S. Public Health Service, and H. A. McCordock, associate professor of pathology, Washington University, states that since the beginning of the outbreak of encephalitis in St. Louis numerous animals of different species have been inoculated with materials of several kinds from patients suffering from the disease. Most of these animals have shown no signs of illness. Six monkeys inoculated with material from five different patients dying of encephalitis have shown fever beginning from the eighth to the fourteenth day after inoculation. Coincident with the rise of temperature tremors, incoordination and weakness have appeared. Three of these animals have been submitted to pathological examination and the central nervous system showed lesions consistent with the pictures found in human epidemic encephalitis.

Inoculation of material from these monkeys into numerous monkeys is also progressing.

While these results are encouraging many weeks' work has yet to be done before it can be stated that the human disease has been established in animals.

It has been found that neither water nor milk is a major factor in the spread of this epidemic, and at present the evidence points to a manner of spread similar to that of poliomyelitis. The precautions to be taken are, therefore, similar to those which would be used in an outbreak of infantile paralysis of like intensity. In the case of such a summer disease, occurring predominantly in suburban sections, the possibility of insect transmission can not be eliminated without intensive and prolonged study. Screening of patients is therefore advised, and measures directed toward the reduction of insects, particularly mosquitoes, are reasonable. There is no evidence, however, which would justify the expenditure, for the prevention of this disease, of the large sums necessary to do really effective mosquito elimination in the area in question.

Precautions have included the isolation of the patient for three weeks. The furnishing by the St. Louis authorities of almost complete hospitalization has also probably aided in more prompt and complete recovery.

The possibility that this new type of epidemic encephalitis may in future years show a more intense prevalence renders urgent as complete a study of this epidemic as possible. Fortunately the mobilization of expert personnel and particularly the remarkable mutual cooperation of the St. Louis and Washington Universities, the medical profession, the hospitals and the health authorities are most favorable to such a study.

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